AGRONOMY FACTS

Volume IV

Issued by Agronomy Department, University of Illinois
During the Period October 1, 1956 to May 27, 1957

AG1763

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AGRONOMY FACTS

THE CLIMATE OF ILLINOIS

Several Agronomy Fact Sheets have been written on the soils of Illinois--their origin, parent material, characteristics, management, etc. But successful agriculture depends also on another thing--climate. In this respect, as well as in their soils, Illinois farmers are blessed far more than the average farmer in the United States. The high prices of agricultural land in Illinois are a direct reflection of high crop yields, which in turn are the product of good soils and good weather.

Illinois lies in the great central plain of North America and covers an area of 56,665 square miles. The distance from the northern to the southern tip is 396 miles, and the maximum width of the state is 215 miles. The topography slopes generally from north to south, and the average elevation is about 600 feet above sea level. Charles Mound in JoDaviess County, with an elevation of 1,241 feet, is the highest point in the state. The lowest point--269 feet--is at the junction of the Mississippi and Ohio rivers. The Illinois is the most important river within the state.

Because Illinois is such a long state, its climate varies widely. The state lies in the paths of the principal frontal systems and, as a consequence, experiences marked changes in weather, especially in the winter. The difference in latitude between northern and southern Illinois is reflected in differences in length of day and in the sun's position. In the extreme northern part of the state, the longest day of the year is about 15 hours and 15 minutes, while at the southern tip the longest day is about 14 hours and 40 minutes. The shortest day is about 9 hours in the extreme north and 9 hours and 38 minutes in the extreme south. The noon sun is always $5\frac{1}{2}$ degrees closer to vertical at the south end of the state than at the north end. These variations in length of day and the directness of the sun's rays are generally responsible for temperature differences between summer and winter and between northern and southern Illinois.

Temperature. Records from 28 weather stations in central Illinois over the past 50 years show the following average monthly temperatures: January, 28 degrees; February, 30 degrees; March, 41 degrees; April, 53 degrees; May, 63 degrees; June, 73 degrees; July, 77 degrees; August, 75 degrees; September, 68 degrees; October, 56 degrees; November, 42 degrees; and December, 31 degrees. Since the climate of Illinois is characteristically continental, July is the warmest month and January the coldest.

Northern Illinois has a wider annual range in temperature than does southern Illinois. Mean temperatures climb more rapidly in the spring and drop more rapidly in the fall in the northern than in the southern section. The wide variations in temperature in winter are caused by alternating invasions of cold and warm air masses for relatively short periods. The polar air masses, originating in Alaska and northern Canada, produce the low temperatures, while warm air masses from the South and Southwest produce the high temperatures. Summer temperatures are controlled primarily by the sun, and therefore the day-to-day extremes are less then than in the winter.

Precipitation. Figure 1 shows the increase in total annual precipitation from north to south. Annual average precipitation ranges from 32 inches in the northeastern part of the state to 46 inches in the south. However, precipitation during the growing season is about the same for the entire state. Actually, however, because of lower temperatures and evaporation rate and the more permeable soil types, plants use a given amount of precipitation more efficiently in northern than in southern Illinois.

May and June are generally the wettest months and July the driest. Measurable precipitation normally occurs during 100 days of the year. The weather is clear on 160 days, partly cloudy on 94 days, and cloudy on 111 days. Relative humidity ranges between 72 and 75 percent in the winter and 64 and 68 percent in the summer.

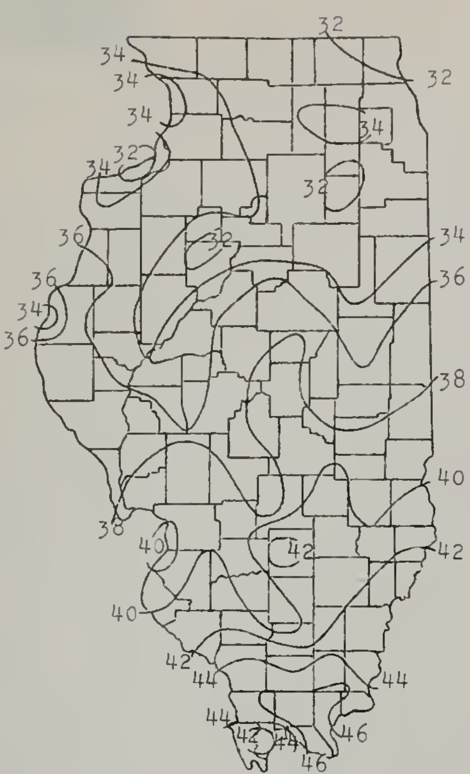


Figure 1.--Illinois Average Annual Precipitation (Inches)

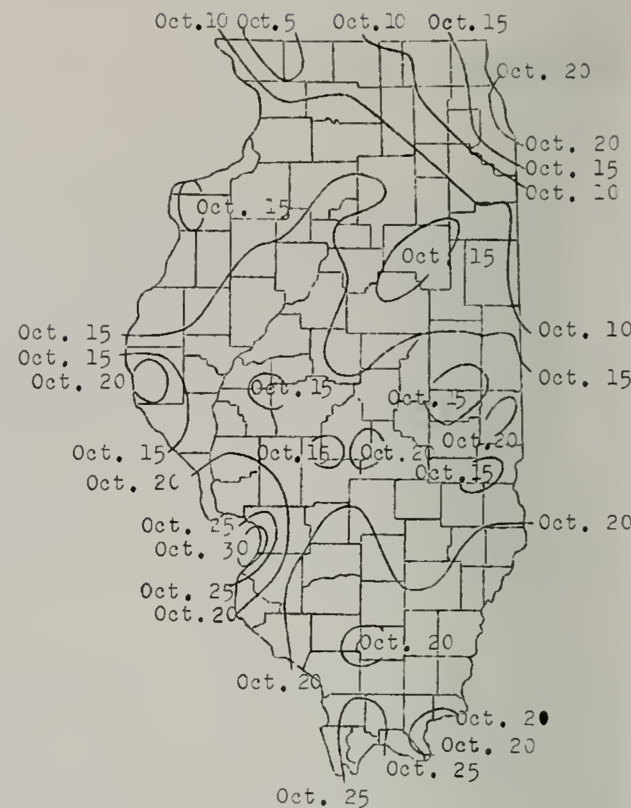


Figure 2.--Illinois Average Dates of First Killing Frost in Fall

Annual snowfall increases from south to north. The average for Cairo is about 10 inches during the winter compared with 35 inches in extreme northwestern Illinois.

Frost and growing season. The average frost-free growing season is 160 days in northern Illinois and 210 days in extreme southern Illinois, giving a 50-day difference.

Figure 2 shows the average dates of the last killing frosts in the spring, and Figure 3 shows the average dates of the first killing frost in the fall. These averages include some tremendous ranges or extremes. For example, frost has occurred as early as August 30 at Freeport, and mid-May frosts are not uncommon in central Illinois.

Winds. Southwest winds are most common in the summer, and northwest winds in the winter. A change of wind direction will cause changes in temperature and relative humidity. The wind is strongest in March and shows the least activity in August.

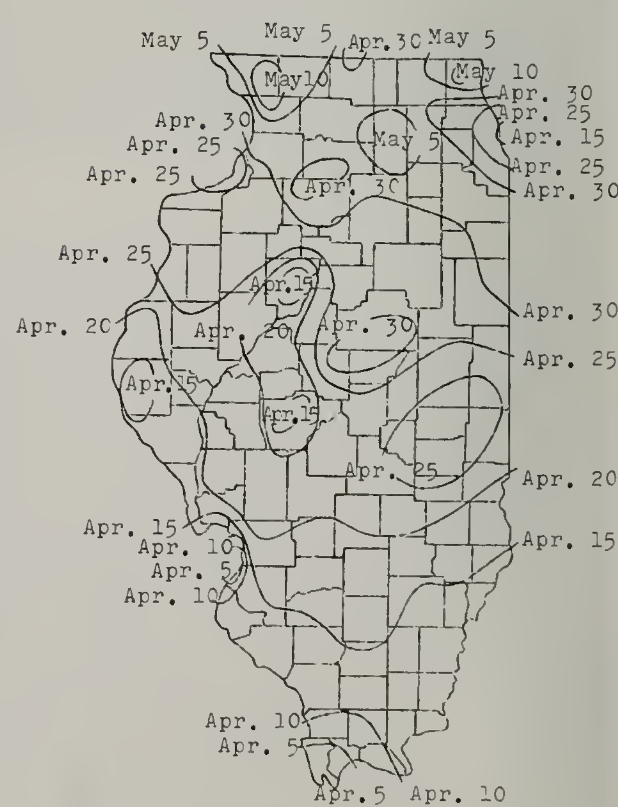


Figure 3.--Illinois Average Dates of Last Killing Frost in Spring

J. W. Pendleton
10-15-56

AGRONOMY FACTS

SEED CERTIFICATION IN ILLINOIS

What is seed certification? Seed certification is a service designed to preserve the purity, increase the supply, and hasten the distribution of pure seed of new and improved strains of crops, enabling the farmer to buy with confidence and satisfaction.

Plant breeders are continually producing new varieties. When a new variety demonstrates its superiority through a series of tests, it is ready to be increased and released to the public. To insure adequate supplies of pure seed of these lots, it is necessary to keep the new variety under seed certification.

How is seed certified? Certified seed, like pedigreed or registered animals, must trace directly back to the original lot or strain. In the hands of the breeder or originator, the supply is known as breeder's seed. Breeder's seed is increased to produce foundation seed, then registered seed, and finally certified seed.

If the purchaser expects to sell the crop he produces as certified seed, he must grow it according to definite rules and regulations, and before harvest he must have it inspected for purity, for freedom from diseases and weeds, and for anything else that might affect the purity and quality of the seed. If his crop meets the standard for field inspection, the next step is to have a representative lot of the recleaned seed inspected in the laboratory for purity, for freedom from weeds, and for germination and general seed quality. Seed that passes these tests is then eligible to be sold as certified and to carry the tag and seal of the certifying agency.

Who certifies seed in Illinois? In more than forty states and the Dominion of Canada, growers' organizations known as crop improvement associations employ trained inspectors to make field and laboratory inspections. In Illinois this agency is the ILLINOIS CROP IMPROVEMENT ASSOCIATION, located at 110 West Green Street, Urbana. The Illinois association was organized in 1922 and incorporated under the Illinois law as an "organization not for profit" in 1924.

Seed certification in Illinois is carried out under the direction of a board of directors elected by the members, an advisory committee appointed by the Director of the Agricultural Experiment Station of the University of Illinois, a public relations officer, a staff of 30 inspectors who inspect the crops in the field and collect samples for laboratory inspection, and an office and laboratory personnel of 15.

How is certification service financed? The cost of this inspection and certification service is borne by the members of the association through membership, farm, field, and acreage fees.

The reserve fund, accumulated over the past twenty years, was used in 1951 to buy a building at 110 West Green Street, Urbana, where the offices and laboratory have been located since 1951.

Who may become a member of the Association? Any resident of Illinois who is a seed grower, contract grower, seedsman, or prospective seed grower, and others interested in promoting the objectives of this association, may apply for membership.

An application for membership may be accepted or rejected by the board of directors following investigation of the applicant's integrity, his interest in better seeds, his ability as a seed grower, and his facilities for producing, caring for, and storing seed.

Any member of the association who first obtains breeder's, foundation, registered or certified seed, who meets the certification standards regarding farm and field eligibility, and who applies for and pays the certification fees in advance of field inspection is eligible to have his grain inspected.

The primary objectives of the association "shall be to promote the interest of agriculture in the State of Illinois by increasing the efficiency of production in Illinois farm crops and the profits to be derived therefrom through improvement in seed and cultural practices. These purposes shall be accomplished by cooperating with the University of Illinois College of Agriculture, Agricultural Experiment Station, and Agricultural Extension Service and particularly with the Departments of Agronomy and Horticulture in a continuous campaign for the more general use of improved varieties and strains."

How do you obtain certified seed? Producers of registered and certified seed are listed in the FIELD SEED GUIDES published by the association and to be found in the offices of the county farm adviser, the vocational agriculture teachers, and the Crop Improvement Association. Twenty-five thousand of these guides are available for distribution throughout Illinois and the Corn Belt.

Summary. Steps in Certification:

1. Start with certified seed.
2. Plant on clean land (one or more years in other crops to prevent volunteer plants.)
3. Isolate: Self-fertilized crops - $16\frac{1}{2}$ feet. Cross-fertilized crops - 20 to 40 rods.
4. Rogue fields.
5. Inspect fields.
6. Sample seed after cleaning.
7. Have tests made in laboratory for purity and germination.
8. Bag, tag, and seal the seed.

J. C. Hackleman
11-19-56

AGRONOMY FACTS

SPECTROGRAPHIC ANALYSIS FOR AGRONOMIC RESEARCH

An agronomist has collected 400 samples of alfalfa in a field study of application rates for boron. He would like to know whether the boron that was applied had any effect on the amounts of other elements in the alfalfa.

Another agronomist is studying the rate of planting for corn. His question is whether the chemical composition of corn stover or corn grain changes with an increase in planting rates.

At a soil experiment field, limestone and dolomitic limestone were applied at different rates some years ago. What changes have occurred in the exchangeable calcium and magnesium in these soils, and to what depths can the changes be detected?

What is the trace element status of the major soil types in Illinois as reflected by amounts of these elements in the soils and in the plants grown in them?

Information on these and similar problems in the Department of Agronomy has been obtained by spectrographic analysis. Cooperative work has also been carried on with other agencies and departments and one other University.

Practically speaking, the spectrograph is nothing more than an analytical tool for determining the chemical composition of agronomic materials. In this sense, spectrographic analysis can offer no more than chemical analysis. Its value lies in the fact that several elements can be determined simultaneously. Spectrographic analysis offers the advantage of a more complete picture of the composition of a sample in terms of labor and time per sample. In terms of speed, the agronomist would have composition data for perhaps 100 samples instead of 20 samples within the same period.

Spectrographic analysis supplies only numbers, which must be evaluated. For example, a corn plant is analyzed and the results are reported as amounts of the various elements in the sample, and the agronomist must then decide whether these amounts are normal, deficient, or toxic. In soil analysis a further complication arises. Spectrographic analysis can be made of the whole soil, different fractions of the soil, or various extracts from the soil. Since it is important to know the amount of an element that is "available," the sample must be the kind that will indicate "available" amounts when analyzed. The same thing, of course, applies to all other types of analytical methods.

In the analysis of plant material, eleven elements are usually determined. Of these eleven, nine are essential elements, four being classified as major and five as trace. The major elements are calcium, magnesium, phosphorus, and potassium. The trace elements are boron, manganese, iron, copper, and zinc. The two non-essential elements are silicon and sodium. Although these last two are classified as non-essential, they are present in plant material and their concentrations are often of interest. This is especially true of sodium, because plant materials from certain areas in the southern part of the state contain large amounts of this element. Except for silicon, the concentration of these same elements can be determined in soil extracts. However, not all ten elements can be analyzed at one time, because it is very unlikely that any one extracting solution would give the "available" forms of all ten.

Spectrographic analysis is not used for routine soil testing. In soil testing, each test requires a specific extracting solution for a specific element. The spectrographic method cannot compete with the soil testing procedures, because a larger number of elements must be determined before the spectrographic method offers any advantage.

J. H. Muntz
12/24/56

AGRONOMY FACTS

MARKET CLASSES A PART OF GRAIN GRADING

Grain Grading

Grain grading has as its purpose the development of standards so that the producer may be paid for the quality of the products he produces. Even a little knowledge and experience in grain grading help the producer to interpret the market price he receives in relation to the quality of the grain he sells. It is only right that the producer (the farmer) should be paid for the quality of his grain.

Standardization is a means to orderly marketing and efficient buying and selling. It traces from the need for a uniform device with which to measure variations in quality as interpreted by the producer, the merchandiser, and the consumer. We have this device in the "Official Grain Standards," a part of the Grain Standards Act. Federal standards are mandatory for grain if it is sold by grade and is to be shipped in interstate or foreign commerce.

Following are some of the tests of grain quality that producers and consumers consider important:

(1) tests for plumpness, which is measured by the weight-per-bushel test, supplemented by sizing tests for some grains;

(2) tests for soundness, which is indicated by the absence of musty, sour, or commercially objectionable foreign odors and by the quantity of damaged kernels that are present in the grain;

(3) tests for dryness, which is determined by making a moisture test;

(4) purity of type, which is provided by "classes" for the various grains and by limitations for admixtures of other grains or of other classes of the same grain; and

(5) tests for condition, which is a general term and refers to whether the grain is in sound condition or is out of condition because it is musty, sour, or heating. Condition is also indicated by such designations as smutty, garlicky, weevily, bright, stained, tough, or treated.

Of these factors of quality, "purity of type" or "class" is the only one that is not influenced either directly or indirectly by environment. In other words, the producer is able to control his product to meet the standards for a specific "class."

Market Classes

Market class in wheat is determined by color of the seed plus kernel characteristics. The market classes of wheat are:

Class I - Hard Red Spring Wheat
Class II - Durum Wheat
Class III - Red Durum Wheat
Class IV - Hard Red Winter Wheat
Class V - Soft Red Winter Wheat
Class VI - White Wheat
Class VII - Mixed Wheat

Market classes usually indicate the particular use that is made of the grain or the products made from the grain. To illustrate, wheat will be used as an example. There are seven market classes of wheat (see listing above).

Hard red spring wheat and hard red winter wheat are known as "bread" wheats. Most varieties, when well matured, yield kernels that are hard and flinty, are rich in protein, and possess qualities that permit large loaves of bread to be baked from a given quantity of flour. The gluten (part of the protein) is of such character that it is elastic and the loaf may increase in volume without breakage of the crust, which when baked

properly has a smooth, even surface. Area of production and kernel characteristics identify the individual class.

Soft red winter wheat and white wheat are known as "pastry" wheats. In general the varieties in these two classes have a lower percentage of protein and a higher percentage of starch than the hard red spring and hard red winter varieties. The quality of the flour is such that it does not make dough with great elasticity. For this reason it is used more for cakes and for biscuits, cookies, and similar products.

Crackers and breakfast foods are usually made from white wheats. Family-type flours are often made from soft red winter wheat. Durum wheat is known as macaroni wheat. Only the amber durums are used for the manufacture of macaroni and similar products, as the red durums produce off-colored products. The red durums are used as feed for poultry or livestock.

Blending wheats or flours to arrive at a desired protein content is a common practice. However, the blending is usually done with wheat or flour from the same or similar class, as a high-protein hard red spring wheat with a low-protein hard red winter wheat. To insure a standardized product, flours going to commercial manufacturers of either bread or pastry products must meet certain specifications. Mixtures of wheats coming from the producer (farmer) or from collection points (the elevator) will therefore be discounted.

While the producer is not always able to prevent weather, disease, insects, or rodents from affecting the grade of his grain, he has no excuse for not meeting a market class. The class of grain he produces is determined by the variety he plants.

R. O. Weibel
4-22-57

AGRONOMY FACTS

CHEMICAL COMPOSITION AND FEEDING VALUE OF GRAIN SORGHUM

The present interest in grain sorghums in Illinois has been largely stimulated by the need of many farmers to conform to the corn acreage allotment program. However, the potential of the new high-yielding hybrids may make this crop more profitable in Illinois than corn on drouthy soils, such as the sands and claypans.

At present it is difficult to market grain sorghums in some areas of Illinois. Local elevators in general are not interested in small quantities of this new crop. Therefore, it will be well for growers to either locate a market before harvest or plan to use the crop for feed on the farm. In all probability most of the crop will be used as feed on the farm in Illinois. Therefore, at present there is a great amount of interest in the feeding value of grain sorghums and how they compare with corn.

Following is the average chemical composition of grain sorghum compared with corn. These data are based on 15 percent moisture.

	Corn %	Sorghum %
Starch	60.8	58.6
Protein	8.9	11.3
Oil	3.8	3.1
Sugar	1.7	1.1
Fiber	1.7	1.6
Ash	1.2	1.5
Nicotinic acid1/	14.7	38.3
Pantothenic acid1/	5.1	8.8
Riboflavin1/	1.3	1.1

1/ Vitamins given as micrograms per gram.

Sorghum grain usually runs higher in protein and lower in starch and oil than corn. Otherwise the two are essentially the same in chemical composition. At several locations in Illinois in 1956, the grain sorghums averaged two to three percent higher in protein than did corn in the same fields.

Grain sorghum makes excellent feed for all classes of livestock. In feeding value, it compares favorably to corn. Recent experiments in Kansas show that it can be substituted for corn pound for pound for fattening beef cattle. In general, the grain sorghums are very palatable, and all classes of livestock relish the grain. Sorghum seeds are so hard that it is essential to grind or crack the grain; otherwise a good portion of the grain will pass through the animal undigested. For cattle, hogs, and sheep, the grain should be cracked or ground, but it is usually fed whole to poultry.

In western states sorghum stubble is often used for pasture after the grain is harvested. After the stalks and leaves are cured or dried, sorghum varieties, which have juicy stalks and leaves, are particularly valuable for after-harvest grazing. However, the plants must be dead and have no secondary growth; otherwise animals may contract hydrocyanic acid or hydrogen cyanide poisoning from them. Frosted sorghum is very dangerous to animals until it has dried out. Keep animals away from frosted plants for at least a week. The most actively growing sorghum plants will also produce hydrogen cyanide poisoning in animals and should not be grazed or fed.

Some growers are interested in grain sorghums for silage. They can be used for silage if harvested in the hard-dough stage, but they produce considerably less tonnage per acre than the regular

forage sorghum varieties. At Dixon Springs in 1956 the grain sorghum varieties produced an average of 11 tons of silage per acre, while the forage varieties produced an average of 19 tons per acre. These yields were computed on a 70 percent moisture basis.

Because of its great drouth tolerance, grain sorghum is often referred to as "dry-land corn." With the advent of high-yielding hybrid varieties, this crop might become important in certain areas of Illinois where lack of moisture may become a problem.

Farmers who grow this new crop will have a good feed crop for all classes of their livestock provided the grain is properly harvested and stored.

E. B. Earley
4/29/57

AGRONOMY FACTS

THE NATURE OF HYBRID VIGOR

Hybrid vigor (heterosis) in plants and animals has been recognized by geneticists for many years. Plant and animal breeders have developed breeding systems that utilize this phenomenon in producing superior types for farmer use. Strangely enough, however, we know little about the genetics of heterosis, even though the increase in value of hybrid corn brought about by it in the United States alone has been estimated to be over one billion dollars a year.

Dr. G. H. Shull, the "inventor" of hybrid corn, coined the term heterosis to describe that state of affairs in which a hybrid is more vigorous than its parents. For all practical purposes, hybrid vigor and heterosis are synonyms.

Corn and sorghum breeders have successfully "harnessed" heterosis to produce superior types for commercial use. For example, the following figure shows a situation that is common in corn breeding.

*Open-pollinated variety

Figure 1

If an open-pollinated variety is self-pollinated, weak, low-yielding, uniform inbred lines "A" and "B" are produced. These lines are much lower yielding than the variety from which they were derived. However, some of these lines are capable of producing extremely high-yielding hybrids, i.e., A x B -->superior F_1 hybrid.

Breeders are not only concerned with finding inbreds that are capable of producing high yield when in combination with other inbreds, but also in finding those combinations that are resistant to diseases and insects, to lodging, and to other hazards. Heterosis is often manifested in these characteristics too.

It is often difficult to make practical use of heterosis in some crop plants. In grain sorghum, breeders are now producing F_1 hybrids on a large scale by using normal pollen-shedding strains as males and interplanted male-sterile (non-pollen shedder) strains as seed parents. The seed set on the female parent is hybrid. Heterosis is quite striking in hybrids of small grains, soybeans, and some forage legumes and grasses. But no method has yet been devised that will permit large-scale hybrid production in these crops. Certain species, like red clover, are self-sterile, i.e., pollen from a plant will not fertilize the female part of the same flower, or any flower on the plant. Thus hybridity is enforced in these species.

Why can't a farmer save seed from his hybrid corn and produce as good a crop the second year as he did the first? Experiments have shown that second-generation seed (F_2) will produce a crop that yields 20 to 30 percent less and that is highly variable in most characteristics compared with the first-generation (F_1) hybrid. Scientists have offered a number

(Continued)

of genetic hypotheses to account for this fact. Three of the better ones are discussed below:

1. Dominant favorable gene hypothesis. Many genes affect yield. Experimental evidence indicates that some of the favorable genes are dominant, i.e., A and other dominant genes B, C, and D bring about high yield. The recessive genes, a, b, c, and d have been found to be less favorable. Inbred A could be said to be genetically AAbbCCdd; inbred B could be genetically aaBBccDD. The hybrid would be genetically AaBbCcDd. Since A, B, C, and D are dominant and favorable, the hybrid would possess all the desirable dominant characteristics present in both parents. In the F_2 generation, recessive combinations (aa, bb, cc, dd) appear and thus reduce the average yield of that generation.

2. Complementary gene hypothesis. Some genes produce greater effects when acting cooperatively than when acting separately. For example, gene combinations A and b, a and B, or a and b produce very low yields, but A and B acting together in a hybrid produce maximum yields (A-B-). Again, as in the dominant favorable gene hypothesis, recombinations in the F_2 would reduce these favorable combinations, and thus reduce the productiveness of that generation.

3. Overdominance hypothesis. Some evidence exists for the hypothesis that maximum productiveness exists when an individual is heterozygous (Aa). Inbred lines are homozygous (aa or AA), and therefore low-yielding. In the F_2, homozygous (AA and aa) individuals appear, reducing the mean performance.

Genetic experiments point out these facts:

1. Hybrids of most crop species exhibit heterosis. If methods could be invented to produce F_1 hybrids in crop plants on a large scale, yields could be expected to increase as they did in corn when hybrids were first introduced.

2. Hybrids lose their vigor in the F_2 generation. If seed is planted from an F_1 hybrid generation, yield is reduced 20 percent or more.

3. Loss of vigor and of uniformity in the F_2 can be accounted for by the recombination of genes and the fact that many of these combinations are less favorable than that which existed in the F_1 hybrid.

D.E. Alexander
5-20-57

AGRONOMY FACTS

STATISTICS IN AGRICULTURE

The word statistics has two distinct meanings when applied to agricultural publications. The first and more common is the descriptive type of statistics, which is illustrated by the graphs usually seen in farm magazines or newspapers. These graphs show trends in prices, the part of the farmer's dollar that goes for costs of various kinds, and that sort of thing. This kind of statistics is usually self-explanatory and will not be treated here.

The other kind of statistics of interest to workers in agriculture is what is called experimental statistics. Experimental statistics is the use of statistical principles to assure proper interpretation of experimental results. This is the meaning of statistics that most agricultural technicians encounter when they read technical bulletins and releases from the agricultural experiment stations. To understand what research people mean by the kinds of words they use in describing their experimental results, it is necessary to review briefly the ways in which statistical principles are applied to research work.

Designing Experiments

A number of statistical principles are necessary for the proper designing of experiments in either the field or the laboratory. There are two major principles, however, that need to be kept in mind in dealing with experimental results. In the first place, the measurements of biological material, such as corn in the field or corn seedlings in the laboratory, are extremely variable from one plant to the next. This variation is caused by the failure of all plants to respond in exactly the same way to the same set of growing conditions. This characteristic is called inherent variability and must be carefully considered when experiments are being laid out.

One way in which variability is controlled is to replicate the treatments that are being studied. If only one plot is planted to each of several fertilizer treatments, then one cannot be sure whether the differences between these treatments were caused by the plot of land on which the treatment was applied or whether they were truly caused by the treatments themselves. If, however, the same treatment is used on several plots, then one has a means of determining whether the differences between treatments are caused by the treatments themselves or by the variability of the soil. This is the principle of replication, and it is essential to the proper interpretation of any experiment.

The second principle used in designing an experiment is randomization, or random assignment. It assures every individual plot of land an equal opportunity to receive any individual treatment in the experiment. In this way the results are not biased by always having one treatment falling in a dead furrow or some other undesirable area of the field. Randomization becomes more important as the experiment becomes more complex, and its importance is emphasized in all descriptions of experimental procedure published for workers in agriculture. With these two major design principles in mind, it is now time to consider analysis of the data itself.

Analysis of Data

Most experimental data are analyzed by a procedure known as analysis of variance. Analysis of variance measures the differences between treatments against the "yardstick" of differences between the replicates of each treatment. In other words, to be sure that a treatment is having a real effect, the difference between two treatment means must be greater than is found between replicates

of the same treatment planted in different parts of the field. With adequate replication in the experiment and randomization in the design, the theory of probability can be used to estimate the significance of differences between treatment means.

Most research workers use analysis of variance as a tool in determining the significance of differences between their treatments in the experiment. Since it is impossible to be 100 percent sure that differences are due only to treatment effects, a probability statement is made which indicates the degree to which the worker is sure that the differences were caused by the treatments. This statement makes it possible to explain the results in a simpler way and make them more meaningful to persons who have to translate them into grower action.

Presentation of Results

The way in which the research results are presented is definitely tied up with the way in which the research data were analyzed. Usually a table of treatment means or averages will be prepared, along with some indication of which means differ from which other means. These significance figures are differences based on the analysis of variance procedure described above. Thus the research man is making statements that he can reasonably expect to be true and that will provide the farmer with reasonable assurance of obtaining similar results.

In many complex experiments the results from one particular factor, like fertilizer, will influence another factor, such as variety. Under some fertility conditions, therefore, variety A is better than B, whereas under other fertility conditions B is better than A. These kinds of results are frequently presented in graphic form so that the reader may see them more easily. Here again the significance of results is measured against the "yardstick" of variability within the experiment itself.

Summary

There are two kinds of statistics in use in agriculture, descriptive and experimental. Experimental statistics are the kind that are applied to research work. To interpret experimental results, it is necessary to remember that the design of an experiment includes the two factors of replication and randomization. By determining the extent to which one replicate varies from another under the same treatment, one can, by an analytical process known as analysis of variance, determine which treatments are producing results significantly different from those of other treatments. These results are then translated into tables with appropriate significance statements to help the reader interpret the results.

W. C. Jacob
5-27-57

UNIVERSITY OF ILLINOIS COLLEGE OF AGRICULTURE

AGRONOMY FACTS

C-11

ESTABLISHING LEGUMES IN CORN

Can corn be used as a nurse crop for establishing hay and pasture crops? This question reverberated like an atomic cannon through the Corn Belt a few years ago when Dr. G. H. Stringfield of Ohio suggested that wide corn rows and better seeding methods might make it possible. Since then there have been minor explosions periodically in several states as both agronomists and farmers set out to test the new idea.

Why so much interest in corn as a nurse crop? It is simply a matter of dollars and cents. Corn is the crop that makes the Illinois farmer the most money per acre. Spring oats, which are the customary nurse crop for hay and pasture seedlings, return the least.

For example, during 1953-54 the average corn yield in Illinois was 52 bushels, while the average spring oat yield was 40 bushels. The average price paid per bushel for corn during this period was $1.49 and for oats 71 cents, or a gross difference of about 50 dollars an acre.

It is our purpose to present here some results and observations from experiments carried on by the Illinois Agronomy Department in recent years on this subject.

What legume species? Lespedeza seems to be the easiest legume to establish under summer seeding conditions. Of the legumes used in central and northern Illinois, alfalfa is the easiest to establish, and sweet clover, red clover, Ladino, and birdsfoot trefoil rate progressively poorer.

When to seed? The best time to seed will depend primarily on which crop the grower wants to favor--the corn or the legume. If he wants to use corn as a substitute for oats in establishing pasture for the following year, then it is important to seed the legume early.

Several experiments have been conducted in Illinois in which the legume was seeded in the early spring ahead of corn. The legume was successfully established, but competition with the corn was terrific, and the corn yields depended upon available water. In 1948 and 1949, Kurtz and Bray obtained excellent corn yields at Urbana from plantings made in established legumes. In similar experiments in southern Illinois and at Elwood in northern Illinois, the corn has failed.

In recent seasons the legumes have been seeded the same day as the corn at Urbana. Over a four-year period, corn yields have not been disappointing under this system. Yields have averaged 92 bushels from 40-inch rows and 65 bushels from 80-inch rows. These yields were obtained with the help of two treatments:

1. A 10-inch band on each side of the corn row was kept weed free.

2. The alfalfa in the corn middles was mowed periodically during the summer.

In four years alfalfa stands have rated good to excellent in this system. The 65-bushel corn yield from 80-inch rows compares favorably with a 62-bushel average oat yield obtained during the same period on an adjacent field. Of course in drouthy areas or even in dry years in humid areas, corn yields would be reduced much more than in these experiments.

If a grower is interested primarily in high corn yields, it would be well to delay seeding. Schaller in Iowa suggests late June as the optimum time. Johnson of Ohio has reported on machinery to use for seeding. Although these dates have not reduced corn yields, the interseeding has not always been successful.

It would not be wise in Illinois to depend upon such a seeding for the next year's hay or pasture. The primary objective of seedings made at last cultivation or in midsummer should be to provide green manure and to control erosion. It is of utmost importance to use a packer-type seeder for these summer seedings.

How to seed. The best method of seeding the legume, when corn is growing, is to use a packer-type seeder. Seeders of that type in 56-inch width are now on the market. Many farmers have simply used grain drills with legume-seeding attachments and removed the drill units that would fall over the corn row. Broadcast-type seeders may also be mounted on either the tractor or the cultivator at the time of the second or third cultivation.

How does wide-row corn yield compare with 40-inch-row yield? Tests show that corn yields decrease as row widths widen. With the same plant population per acre, 60-inch rows produced 92 percent and 80-inch rows 80 percent as much corn grain as 40-inch rows.

Does row direction matter? Yes, if the legume is established at the time of the last cultivation or later, the corn rows should be planted in a north-south direction. Often a good stand is obtained uniformly across the corn middles only to have the small seedlings die later in the sunny areas of the east-west planted rows.

Interseeding corn with a legume crop remains a tremendously challenging agronomic problem. Water or rainfall remains the key to the success of such a venture. In wet years, interseeding corn with a legume will be highly successful, while in other years the interseeding will fail. Researchers will continue to seek methods to improve the chances of success with this cropping system.

J. W. Pendleton
10-1-56

SKIP-ROW PLANTING OF CORN

Skip-row planting of corn is a modified wide-row spacing system whereby two rows are planted at regular row width and then one row is skipped. In 40-inch rows this means that the alternate spacing between rows becomes 40 and 80 inches. It is possible to have a living intercrop in 40 or 50 inches of the wide 80-inch area. This intercrop can be an established stand or a newly seeded stand. When the corn and intercrops are rotated, the pair of corn rows are centered in the previously skipped or intercropped area.

What are some of the advantages and disadvantages of skip-row planting? The possible advantages are:

1. An established intercrop, by providing frequent buffer strips, will help to control erosion.
2. It might be possible, by relocating rows on a field at intervals, to have the field planted two-thirds to corn and one-third to a soil-improving crop each year.
3. By growing corn continuously in a skip-row system, it is possible to eliminate a small-grain nurse crop.

The disadvantages of the system are:

1. The intercrop competes with corn for soil moisture and hence is apt to reduce annual corn yields.
2. The intercrop will require clipping to control weeds.
3. Intercrops, to be successful in controlling erosion, must be seeded before corn planting.
4. Special machinery may be required to prepare seedbeds for corn and to clip weeds in intercrops.

Skip-row planting reduces yield. In one study over a three-year period, skip-row-planted corn with a living intercrop yielded less than corn planted in 40-inch rows with an intercrop and less than corn in 40-inch rows with clean tillage (Table 1). In 1953 and 1954 the living intercrop (15 inches wide in 40-inch rows and 50 inches wide in 80-inch skip-row) was provided by an established alfalfa stand. In 1954 the corn yields were from second-year corn planted with the same intercrop strips used in 1953. Corn yields from skip-row planting were reduced 19.1 bushels (25%) in 1953, 14.8 bushels (14%) in 1954, and 53.8 bushels (91%) in 1955 compared with yields from 40-inch planting with clean cultivation.

Table 1.--Effect of Living Intercrop on Corn Yields, Elwood, Illinois

Tillage	Row width	Yields 1953	1954	1955
		Bu./A.	Bu./A.	Bu./A.
Clean cultivation	40"	76.0	106.6	59.2
Living intercrop	40"	66.6	97.9	12.1
Living intercrop	40"-80" (skip-row)	56.9	91.8	5.4

Information was also obtained on the effect of mulch management on yields. In 1953 highest yields were secured by clipping the intercrop frequently and by placing the residue as a mulch in the corn row. In 1954 there was an increase in corn yields from frequent clipping of the intercrop, but yields were not further

(Continued)

improved by using the residues as a mulch in the corn row. In 1955, which was an extremely dry and unfavorable growing season, frequency of clipping or mulching management had no effect on yields.

Intercrop studies. In an effort to determine the best kind of intercrop and the proper method for establishment, a study was initiated at the Elwood Station in 1954. Prior to 1954 several seedings were made to get some preliminary information on crops to include in the study and time when seeding should be made. The study provides for establishment of early-seeded legumes in a cornfield prior to corn planting. The intercrop established by this seeding will remain in place for two years, permitting both first- and second-year corn production. In addition to early-seeded legumes, summer-seeded crops, such as rye and winter vetch, were also established late in the summer, around the first of August.

It appears that the success of skip-row planting will depend upon the availability of soil moisture for corn. In 1954, a good growing season with adequate moisture available for the crop, the skip-row corn with intercrops yielded more than skip-row corn planted without an intercrop (Table 2). In 1955 the yields from the fallow skip-row plots were extremely low. When spring-seeded intercrops were used, the corn yields were reduced to 14 bushels per acre, which was only 45 percent of the yield of 30.9 bushels per acre on the check plots. On second-year corn the yields from plots with a spring-seeded living intercrop were reduced 70 percent.

The competitive effect of the intercrop was not nearly so great when the intercrop was seeded late in the summer. However, late seeding of the intercrop does not permit sufficient growth to protect the field against erosion losses during the hazardous period in May and June, when most of the soil losses occur from our cornfields.

Table 2.--Effect of Kind of Intercrop on Corn Yields With Skip-Row Planting

	Corn yields		
		1955	
Intercrop	1954	First year corn	Second year corn
	Bu./A.	Bu./A.	Bu./A.
Check - fallow	85.1	30.9	41.4
Winter vetch	90.6	34.3	40.1
Rye	91.7	23.8	26.9
Alfalfa	87.7	11.3	11.6
Red clover	87.7	--	14.9
Alfalfa - red clover	--	12.1	--
Mammoth clover	85.8	16.5	11.8
Ladino clover	87.3	16.2	11.9
AVERAGES			
Spring seeded	87.1	14.0	12.6
Summer seeded	91.2	29.0	33.5

Soil samples secured for soil moisture determinations indicated that the alfalfa and ladino intercrops were withdrawing approximately the same amount of water from the soil to a depth of 24 inches. These early-seeded intercrops were definitely competing with the corn for soil moisture.

Comments. The final evaluation of skip-row farming will be based largely on total net income from the land over a period of years. Corn is a high-profit crop, while on many grain farms oats and hay are much less profitable. In the long-term analysis, corn yields may be lower in a skip-row or wide-row system than in a rotational system and still be acceptable, since corn appears more frequently and low-profit grain crops may be eliminated. If, however, severe reductions in yields are obtained frequently as a result of intercrop competition, the skip-row method will not be favorably accepted by growers.

The combinations of row crops and forage crops that offer the highest maximum production need further study and development. When these combinations are developed and proved to be satisfactory, this system of farming could lend itself to balanced annual production and good soil conservation.

R. E. Burwell
11-5-56

UNIVERSITY OF ILLINOIS COLLEGE OF AGRICULTURE

AGRONOMY FACTS

C-13

DWARF CORN HYBRIDS

Promising results have been obtained during the past two years with new dwarf corn hybrids. These hybrids, which grow about four feet high, have shown outstanding resistance to lodging and have produced good yields in tests at Urbana and Brownstown. Farmers and seedsmen who have seen them have expressed interest in them, and further intensive investigations of field performance are planned. The answers to the following questions present the major information that is now available.

How do these dwarfs differ from normal hybrids? The chief difference is that the stalk joints (internodes) of the dwarfs are much shorter than those of normal plants. The internodes below the ear rare only one to three inches long instead of six inches or more as in normal corn. The number of internodes and leaves is essentially the same in dwarf hybrids as in normal types. As a result, the dwarfs average about four feet in height, and their ears are 12 to 20 inches above the ground. The ear height of comparable normal hybrids grown under the same conditions ranges from 42 to 56 inches.

How have these dwarf hybrids been produced? Dwarf hybrids now under study have been produced by incorporating the single recessive genetic factor brachytic 2 into desirable standard inbred lines. This has been done by a program of backcrossing, selfing, and selection. Except for height the resulting dwarf lines have plant and ear characteristics similar to those of the corresponding normal lines. Since the dwarfing factor is a recessive genetic trait, it has to be incorporated into all four lines of a double-cross hybrid if a dwarf type is to be produced.

How well do the dwarf hybrids yield? This year (1956) was the first in which dwarf double-cross hybrids were grown and compared with normal hybrids. Four dwarf hybrids tested at Urbana, where yields were very high, yielded about 20 percent less than the average of two desirable standard hybrids, Illinois 1421 and U.S. 13. At Brownstown, where tests were conducted both on Cisne silt loam (prairie soil) and on Wynoose silt loam (timber soil), the dwarf hybrids yielded virtually the same as four comparable standard hybrids. Yield data from these tests are summarized in the table below.

Hybrid	Urbana	Brownstown Cisne soil	Brownstown Wynoose soil
	bu.	bu.	bu.
Dwarf hybrids			
(9 x 2) (Fr6 x 678)	118	87	50
(9 x 2) (Ha6 x 31)	109	74	55
(9 x 2) (6D x 31)	111	79	45
(9 x 2) (Ha6 x Fr5)	108	71	43
Average, dwarfs	111	78	48
Normal hybrids			
Illinois 1421	140	83	..
Illinois 21	...	79	..
Illinois 1332	...	82	..
U.S. 13	136	86	..
Average, normals	138	82	46

(Continued)

These data, taken together with results from single-cross tests conducted in 1955, indicate that present dwarf hybrids may yield almost as much as good normal hybrids at productivity levels in the 50- to 85-bushel range. At higher productivity levels, there is reason to believe that these dwarf hybrids will yield 10 to 20 percent less than desirable standard types.

What advantages may dwarf hybrids have? The major obvious advantage is their extreme resistance to lodging. In 1955, dwarf single crosses were 100 percent erect at harvest, while comparable normal hybrids ranged from 45 to 90 percent erect. In 1956, both dwarfs and normals were 100 percent erect when harvested in early October. However, in plots that were not harvested until the last week in November, the normal hybrids averaged 38 percent erect, while the dwarfs averaged 99 percent.

This drastic reduction in lodging offers hope that harvesting losses can be considerably reduced by growing dwarf hybrids. Other probable advantages include easier handling by corn combines, less shading of interplanted legumes, and lower water requirements. However, experimental data have not yet been obtained on any of these points.

What are the possible disadvantages of these dwarfs? The main obvious disadvantage is the likelihood of lower yield, at least under highly favorable growing conditions. Although this lower yield may be partly or entirely offset by reduced harvesting losses, it is nevertheless of major concern. Also, there is some indication that the dwarf hybrids now being studied may be more sensitive to crowding than standard hybrids. Late growth of weeds, particularly the grassy types, between rows is also a potential problem, because the dwarfs do not shade the ground so densely as do normal types.

What further experimental work is planned? Breeding work will be continued and intensified. Main emphasis will be placed on developing the best possible dwarf versions of standard hybrids. In 1957, intensive studies of cultural practices with dwarf hybrids will be started. These studies will include row spacings, planting rates, response to irrigation, response to various fertility levels, and harvesting trials with the corn combine, picker-sheller, and standard picker equipment. A series of trial plots in farmers' fields is also being planned. The results of these trials will be used as a basis for recommending whether desirable dwarf hybrids can be produced and grown successfully.

When will seed of dwarf hybrids be available? The only answer now possible to this question is that none will be available in the next year. Experimental results do not yet make it certain that seed of the dwarf lines or hybrids should be released to the public. A decision on this point should be possible within the next two years. If the dwarf hybrids prove feasible for farm use, limited quantities of seed should be available for general distribution within the next five years. Initially seed release would be handled through the Illinois Seed Producers Association, according to the "delayed release" program customary with new inbred lines produced by the Illinois Agricultural Experiment Station.

Earl R. Leng
11-26-56

BREEDING CORN FOR HIGH-POPULATION PLANTING

The normal planting rate for corn in Illinois is usually 12,000 to 16,000 plants per acre. The optimum rate for any specific farm depends upon the soil type, the fertility level, and the outlook for an adequate water supply during the growing season.

It has recently been found that certain hybrids do poorly if planted above certain maximum rates and, conversely, that a few hybrids withstand the usually damaging effects of too dense populations and manage to produce satisfactory yields. According to Lang, Dungan, and Pendleton of the Illinois Agricultural Experiment Station, hybrids showed different yield responses to both nitrogen levels and plants per acre in trials conducted by them in 1952 and 1953 at Urbana.

The single cross Hy2 x 07 was the "star" in these trials. At 24,000 plants per acre, this hybrid averaged 128 bushels on high-fertility plots, whereas the nearest competing hybrid yielded 118 bushels at the same planting rate. The highest mean yield obtained at any rate by any hybrid in these trials was 143 bushels. This value was reached by Hy2 x 07 at 20,000 plants per acre on fertile soil.

Heredity unquestionably accounted for the ability of the single cross Hy2 x 07 to yield well even at populations above the optimum for the environment in which it was grown. With this fact established, a program was started in 1953 whose objectives were:

1. To determine how frequently inbreds might be found that possess hereditary "resistance" to the damaging effects of crowding.
2. To determine whether satisfactory "high-density" double-cross hybrids could be produced with Hy2 x 07 as one parent and combinations of new inbreds as the other.

In 1953, 808 relatively untested inbred lines of corn were crossed with the single-cross tester parent, Hy2 x 07. The following year these three-way hybrids were tested in two locations in the state at 24,000 plants per acre. From this test the 65 best hybrid combinations were chosen and tested in 1955 at Urbana at the same rate. The top 30, as determined by this test, were again tested in 1956 at Urbana. Performance of some of these hybrids is summarized in the table on page 2.

Although these data are not wholly convincing, it appears that certain of the experimental inbreds combine well with Hy2 x 07. Five of the 30 three-way hybrids tested in 1956 did not yield significantly less than Hy2 x 07.

The results in the table show a weakness of conventional-height hybrids grown at these high densities. They are susceptible to lodging. However, a great deal of lodging also occurred in 1955 in hybrids planted at much lower rates. The official test of commercially available hybrids at Urbana averaged 60 percent of erect plants at 16,000 plants per acre. It can be expected that further breeding will improve the standability of experimental hybrids planted at these high populations.

Further testing of three-way hybrids is to continue. A number of experimental double crosses that involve Hy2 x 07 and combinations of new inbreds will be tested in 1957.

Performance of Experimental Hybrids at
24,000 Plants per Acre, Urbana, Illinois

Pedigree	1955 Yield	1955 Erect plants	1956 Yield	1956 Erect plants
	bu/a1/	pct.	bu/a2/	pct.
Hy2 x 07	129	32	148	93
(Hy2 x 07) 269B	101	46	145	90
(Hy2 x 07) 220A	112	36	138	90
(Hy2 x 07) 44-1A	92	24	138	82
(Hy2 x 07) SS69	122	32	138	94
(Hy2 x 07) 264B	115	66	137	82

1/ Differences of less than 8.6 bushels per acre not statistically significant.
2/ Differences of less than 11.5 bushels per acre not statistically significant.

D. E. Alexander
1-7-57

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

AGRONOMY FACTS

C-15

MINIMUM TILLAGE FOR CORN

Since 1950 several promising new methods for preparing corn seedbeds have been tried. They are (1) wheel-track planting, (2) planting on plowed ground with a leveling-packing tool attached behind the plow, (3) plow-planting, (4) mulch-tiller planting, and (5) ridge planting. They require much less work and seem to offer other advantages over conventional methods.

"Minimum tillage"--as the new methods are called--has five aims:

1. To save labor by reducing the number of trips over the field.
2. To reduce soil packing from heavy wheel tractors.
3. To increase the rate at which water enters the soil by leaving the surface loose and open.
4. To reduce soil erosion by reducing water runoff and by leaving the soil in small aggregates or granules which are less easily carried off the field by water or wind.
5. To reduce weeds by leaving the soil surface too loose for annuals to germinate and by causing the broken rootstocks of perennials to lose contact with the soil and thus dry out and die.

In a typical schedule--plow, disc once or twice, harrow, and plant--at least four total trips are made over the field, and often more. Rotary hoeing, weed spraying, and several cultivations can raise the total to 10 or 11.

With a modern heavy tractor, each trip leaves tire tracks on strips of soil 3 feet wide, and about every four trips could lay a track on each square foot of soil.

What harm does this compaction do?

To date no one has a full answer, but a close look within the soil raises further questions.

The accompanying drawing represents a cross section through the plow layer with a tractor track through the center. Note the compacted zone. It is not immediately below the track. Why not? Because dry soil doesn't pack easily, and the top few inches always dry first after a rain. But the soil 4 to 8 to 12 inches down may still be wet enough to pack considerably. Cultivator shovels behind the wheel cannot reach this deeper, hidden zone of compaction.

There are exceptions to this pattern, of course. If the whole plow layer has a uniform moisture content, packing may start right at the surface. During a long drouth period, when the entire layer of topsoil is dry, there will be little or no compaction.

Many people mistakenly believe that minimum tillage means that the corn is planted in a rough, loose, coarse seedbed. Actually, although the field looks rough, a <u>good seedbed</u> is prepared <u>in the row itself</u>.

Plow With Packer-Leveler

Most Corn Belt farmers like fall plowing and early spring plowing where the erosion hazard isn't serious. They need a minimum-tillage method suited to four-row planting and cultivating.

Fall-plowed ground and early spring-plowed ground are usually firm by corn-planting time. A level-packing tool behind the plow would help to firm spring-plowed fields.

One way to adapt minimum tillage to four-row operation is to pull a spike-tooth, rotary hoe (backwards), Valley tiller (formerly <u>Ezee Tiller</u>), Snowco spiral roller, sheepsfoot packer, or similar tool behind the plow to level and firm the soil. You can then plant with a four-row planter. Michigan agronomists have studied this method since 1956. It works well in a soil with good tilth and good moisture content.

You will need experience to know when you are getting enough firming. A carrier wheel mounted on the planter frame in front of each planter shoe or a pneumatic tire in place of the steel-rim press wheel would help to firm the row. On fall-plowed fields, cultivator sweeps on the front of the tool bar would kill weeds, large and small. Spray equipment could be mounted for pre-emergence weed control.

This plan has wider practical possibilities at the present time than any other minimum tillage method for Corn Belt farms. The right packer tool and some additional working in the row--perhaps with rotary hoe sections or special packer wheels for the row-area--will adapt it to a wide range of soil conditions.

Wheel-Track Planting

Wheel-track planting was started by R. L. Cook at Michigan State University in 1946. The field is usually plowed just ahead of planting so that the furrow slice doesn't have time to dry out and get hard and rain can't intervene. A small tractor is needed if the wheels are to be set in the usual corn row width. Using a two-row planter places the corn row directly in the tractor wheel tracks. The soil is firm around the seed. The corn germinates and comes up quickly.

The tractor wheel makes a good seedbed even in a cloddy field, provided planting follows plowing before the clods dry out and get hard. The soil between the rows--except the front wheel tracks on tricycle tractors--is loose and open. Weed seeds in this soil germinate slowly in a normal season--sometimes not at all in dry seasons.

This method works well on a wide range of soils--from sands to clay loams. Planting when the soil is too wet will cause severe packing in the row. Hundreds of farmers throughout the Corn Belt now plant in wheel tracks.

Some farmers, like Orson Hill, Creston, Illinois, have their own modifications. He was perhaps the first to add two extra rear tractor wheels spaced for use with a four-row planter.

Planting two rows at a time will handle up to 60 to 80 acres of corn per farm, but it is too slow for larger acreages. Another problem with large acreages is the delay in plowing. Delayed plowing is fine on sod in a wet year, but it will seriously dry the soil to the rooting depth of the sod in a dry spring.

Plowing and Planting at the Same Time

Plow-planting combines plowing and planting into a single operation. R. B. Musgrave of Cornell University (formerly from Illinois) developed the method. He mounted the planter unit on the plow frame. In 1956 he attached the planter unit to the cultivator mounting on the tractor and hung a fertilizer tank on the other side of the tractor.

A 3-bottom, 14-inch plow can plant one row at a time with 40 to 42 inches between the rows. A 5- or 6-bottom plow is needed for two rows. The planter unit raises and lowers with the plow. A depth gauge straddles the planter shoe to level and firm the row area and control the planting depth.

Plow-planting has several advantages: It is truly a once-over operation. It leaves no tracks for water to channel and run downhill. The row is centered on the furrow slice in contrast to being placed at random on and between slices when planting is a separate operation. The area between rows is not packed. Neither annual nor perennial weeds grow as well as in a firmed seedbed. Water infiltration is increased to a maximum.

Plow-planting also has some disadvantages: Plowing is delayed until planting time. The method is slow compared with four-row planting on a prepared seedbed. In a wet spring, however, when plowing is delayed, a farmer can get his corn planted sooner with two tractors equipped to plow-plant than with one tractor plowing,

disking, and smoothing and the other planting. Plow-planting works only on soils in good tilth. In a dry spring, letting a sod grow until planting time will dry it out too much. The corn can be cultivated two rows and oftentimes four rows at a time.

Results from eight trials made by the Departments of Agronomy and Agricultural Engineering plus eight by the Farm Adviser in Henry County, Illinois, in 1956 indicate that corn can be satisfactorily grown by this method.

Till Planting

The International Harvester till planter prepares a seedbed and plants two rows in one trip. The corn row is prepared with a narrow, deep-running sweep, a wider sweep that runs shallower, and rotary hoe sections. The strip between rows is left unstirred. In sod, this strip can be cultivated out later. Till planting on the contour is an excellent soil conservation measure.

In experiments with sod between rows, till planting reduced corn yields. The greatest reduction, of course, occurred in dry years. Extra fertilizer is applied to make up for the nutrients not released from the unplowed sod strip between the rows. This doesn't apply when till-planted corn follows corn or soybeans.

Some of the disadvantages of till planting are that it is only a two-row operation, the entire operation is delayed until corn-planting time, the plant growth between rows competes for moisture in dry seasons, extra fertilizer is needed following sod, and a special machine and considerable power are required.

Ridge Planting

At Iowa State College, engineers turned a 14-inch furrow slice on top of a 28-inch unplowed strip on the contour. The corn row was centered on the ridge top, and a single-disk furrow opener was used in place of the planter's runner shoe. In these trials, yields have been about equal to those with conventional methods. Corn rows can be planted for two years on the same ridges. The advantages are fewer trips over the field, less water runoff and erosion, and less drowning of corn in flats or depressed areas.

Seedbed and Rootbed

So far, we have looked at minimum tillage methods from the standpoint of the seedbed. But the rootbed needs attention too.

In five locations in New York and Illinois, where emergence of plow-plant corn was equal to that on a conventional seedbed, the corn grew to about eight inches and then seemed to stand still for two weeks. Although it eventually caught up, this slowdown is not desirable. No satisfactory explanation was found for it, because the soil moisture was about the same down to the 16-inch depth.

Here is the tentative explanation: The secondary roots on corn develop nearer the surface than the first roots. When corn is 8 to 10 inches tall, the secondary roots extend out from the narrow row area in which a partial seedbed was prepared. Possibly they do not get enough water or nutrients in a coarse rootbed because they just don't contact enough soil.

If this explanation is correct, the first cultivation or weeding in a dry year should be made as soon as the corn is high enough not to be covered. In a wet year you could delay the first trip over the field after the corn is up until weeds need to be killed.

Substitutes for Plowing

It is hard to beat the moldboard plow in humid regions. It works well on both sands and clays, and with every cover from tough sod to cornstalks. No tool is more efficient in the use of power. No tool results in fewer weeds.

Some farmers in Illinois are using the Graham "plow," a chisel-type implement, on soybean stubble in silty-clay loams.

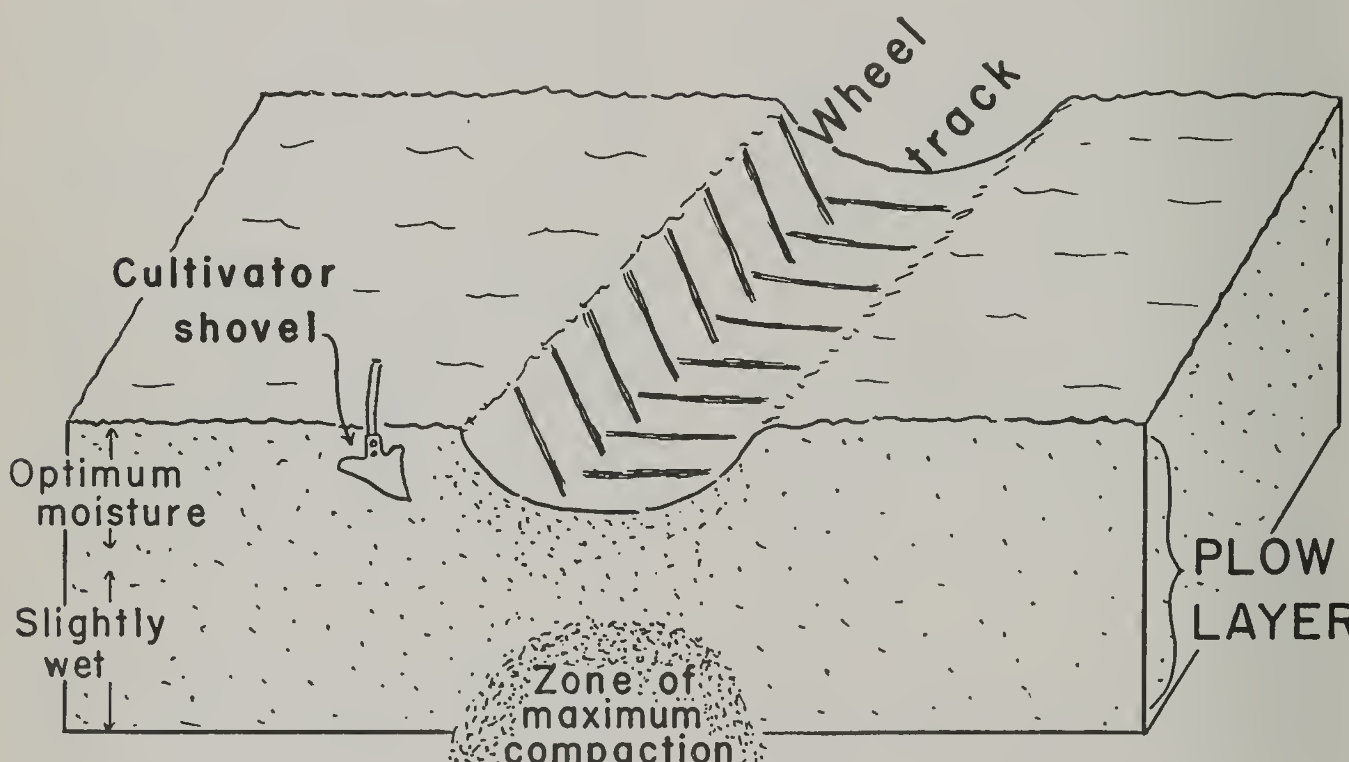
The soil dries in the few surface inches, but is sticky deeper in the plow layer. The Graham does not turn up this plastic layer, which often dries hard and cloddy.

A disk or field cultivator might be as effective, since the Graham blades may cut little more than a slit through the tight, sticky subsoil.

Rotary-type tillers of the type now available to farmers break down the soil structure in the plow layer, leaving the surface vulnerable to crusting after hard rain. The finely pulverized surface also speeds weed-seed germination.

No one claims that minimum-tillage methods will produce more corn than conventional methods, although they may in some years on sloping fields where much of the rainfall often runs off. If they yield as well, their other advantages should recommend their adoption. On fields that are cropped heavily to corn and soybeans, there may be a desirable cumulative effect of minimum tillage on tilth that does not show up the first year.

Results to date from minimum tillage indicate that many farmers work their fields more than is necessary.



Samuel R. Aldrich
2/11/57

STAGES IN THE DEVELOPMENT OF THE CORN PLANT

There are four major stages in the development of the corn plant, starting with the seedling and terminating with the mature seed. They are the vegetative, the transitional, the reproductive, and the seed stages. In each of these stages the developmental activities are different.

Vegetative Stage

The first stage is primarily vegetative. Leaves are the factories in which many of the products for growth are produced. They differentiate and develop from the growing point of the main stem, which is short and shaped like a half sphere.

The internodes of the stem remain short. Lateral shoots are produced, one in the axil of each leaf, except that none is formed in the axil of the leaves after the tassel begins to differentiate. The lateral shoots produced in the early stage of plant development may become suckers, but the lateral shoots produced later may develop into ears.

Transitional Stage

The transitional stage is short, consisting only of elongation of the stem apex. This elongation occurs in the main stem, giving rise to the tassel, and in the lateral branch (or branches), giving rise to the ear (or ears).

Reproductive Stage

Two developmental changes in the main stem indicate the beginning of the third stage of development and the end of the preceding stages. The internodes begin to elongate. Elongation of the internodes of the main stem increases the height of the plant and causes the tassel to emerge from the leaves that envelop it. Elongation of the main stem terminates with the maturity of the tassel. The tassel develops from the elongated transitional stem apex of the main stem. The first tassel structures that form are the branch initials, but only those branch initials at the base of the tassel elongate. The remainder of the branch initials on the central axis of the tassel and those that develop later on the side branches of the tassel divide into two unequal parts, forming the spikelet initials. Two flowers form from each spikelet, and in each flower three anthers, which contain the pollen, are produced.

The lateral shoots of the main stem, from which the ear or ears develop, follow a pattern similar to that of the tassel but with certain exceptions. The apex of the ear shoot elongates, branch initials are formed, and each branch initial divides into two unequal portions to form the spikelet initials.

One difference in the development of the flowers of the ear from those in the tassel is that in the ear the pistil develops and the anthers fail to develop. Another difference is that in each spikelet of the ear two flowers start but only the upper and larger flower develops into a kernel, while in the tassel both flowers develop. The lower or smaller flower of the ear aborts. Therefore for each pair of spikelets there is a pair of kernels. The result is an even number of rows of kernels on the ear. The germ of the kernel that develops from the upper flower of the spikelet is on the side toward the tip of the ear.

In Country Gentleman sweet corn, both flowers of the spikelet develop kernels. The germs of the kernels produced from the upper flower face the tip of the ear, and the germs of the kernels produced from the lower flower face the butt of the ear. When both flowers of a spikelet produce kernels, the rows are very irregular because the kernels crowd each other out of line.

Seed Development

All of the development in the first, second, and third stages sets the stage for the final stage, seed development. The anthers shed their pollen, which falls upon the silks. Within five minutes after the pollen grain lights upon the silk, the pollen grain germinates and the pollen tube emerges and begins to enter the silk. The pollen tube containing the two male sperms grows down inside the silk to the ovary, which is attached to the cob. The pollen tube enters the embryo sac, and the male sperms escape from the pollen tube. One of the sperms unites with the egg nucleus to form the embryo of the young plant. The other sperm unites with the two endosperm nuclei to form the endosperm, the food supply.

Various workers have reported that the pollen tube enters the embryo sac within 15 to 24 hours after pollination, depending upon the temperature and the length of the silk. If a silk is six inches long, the pollen tube therefore grows to about 1,500 times the diameter of the pollen grain. It has been estimated that as many as 9,000 pollen grains may be produced for every silk. But, although many pollen grains fall upon a silk, germinate, and send pollen tubes down the silk, only one pollen tube enters the embryo sac.

Fertilization of the egg nucleus and the endosperm nuclei occurs within 26 to 28 hours after pollination. The fertilized endosperm nucleus begins to divide at once, but it is 10 to 12 hours after fertilization before the first division occurs in the fertilized egg.

The Corn Kernel

The corn kernel begins to develop with fertilization of the egg and endosperm nuclei. Four days after pollination the embryo and endosperm have begun to develop. After 18 days the embryo has taken shape, and the endosperm occupies most of the ovary. Twenty days after pollination 89 percent of the seeds will germinate, but the percentage of strong seedlings is low. About 45 days after pollination, the corn kernel has reached full maturity and begun to dry.

Maturity of the corn kernel marks the end of the fourth stage of development of the corn plant. The plant begins to die. The corn kernel contains a young plant that has roots and a shoot. The shoot has a growing point enclosed in four or five rudimentary leaves. The endosperm is packed full of starch and other food nutrients. Seed coats consisting of the pericarp (ovary wall) and the outer cells of the nucleus are mature and enclose and protect the tiny living plant and its food supply.

O. T. Bonnett
3-18-57

AGRONOMY FACTS

WATER USE BY CORN

High levels of corn production in the Corn Belt probably depend more on water relationships than on any other factor influencing growth and reproduction of plants.

Source of Water Used by Plants. The water that corn uses for growth is derived from two basic sources. Part is supplied by summer rainfall. For much of the Corn Belt, however, at least 50 percent more water is required to produce high yields of corn than is supplied in the normal rainfall for the months of June, July, and August. High levels of production therefore depend to a considerable extent on utilization of water stored in the soil profile.

The amount of water stored in the soil profile that is available for plant use depends principally on soil texture, modified by profile characteristics that may inhibit root penetration.

In a uniform soil, sands will hold from 3 to 6 inches, sandy loams from 6 to 9 inches, and silt and clay loams from 9 to 13 inches of available water to a depth of 5 feet. The better corn soils of Illinois fit into the silt and clay loam category; that is, they will have from 9 to 13 inches of plant-available water if the soil is fully recharged at the beginning of the season.

Causes of Water Loss. The seasonal potential use of water is illustrated in Fig. 1. The greatest potential use of water occurs during the months of June, July, and August. Excluding runoff, water is lost by evaporation from the soil surface and by transpiration through plant leaves. Evaporation from the soil surface is controlled principally by the evaporative demand and the water content of the soil. Transpiration is controlled principally by the evaporative demand and the amount of leaf surface area.

Seasonal Use. The rate at which water is lost from soil in a corn field is small at the beginning of the season and increases toward a maximum in mid-July, remaining essentially constant thereafter until harvest. The use by corn through the mechanism of transpiration is controlled by two factors. Fig. 1 shows that the evaporative demand is greatest in July and August. Fig. 2 shows the probable extent of leaf surface area as the season progresses. The leaf surface area reaches a maximum around July 1 and remains constant thereafter. Consequently evaporative demand and leaf surface area reach a maximum at approximately the same time. The coincidence of these two factors results in a maximum usage of water. Thus the months of July and August become critical times in terms of the water economy of the corn plant.

Soil Pattern of Use. The total withdrawal of water from the soil follows the pattern mentioned above; that is, the rate of loss increases as the season progresses. The position in the soil profile where water is being withdrawn reflects the extension of plant roots into the profile. Early in the season the roots are most active in the topmost zones, and the water is quickly withdrawn from the plow layer. Soil water evaporation is likewise accelerated during this period. As the season progresses, the roots extend deeper into the soil and the zone of maximum water use also extends deeper. Under row crops, such as corn, there is a lateral extension of roots, and consequently a lateral extension of water use. The net result of these root extensions is that during the critical periods of July and

August the corn plant must utilize water stored in the lower subsoil during the winter and early spring.

Any factor that prevents roots from utilizing water in the lower depths, that is, lack of subsoil recharge or profile characteristics such as clay pans, will greatly influence corn growth and reproduction occurring during July and August. This situation will not be detrimental, however, if more than the normal amount of rain falls in July or August, such as occurred in 1956.

Total Amount of Water Needed. Under average conditions in Illinois, a total of 15 to 20 inches of water will be used during the growing season. Of this amount 7 to 12 inches will be supplied by summer rainfall. The remainder must be supplied by profile recharge.

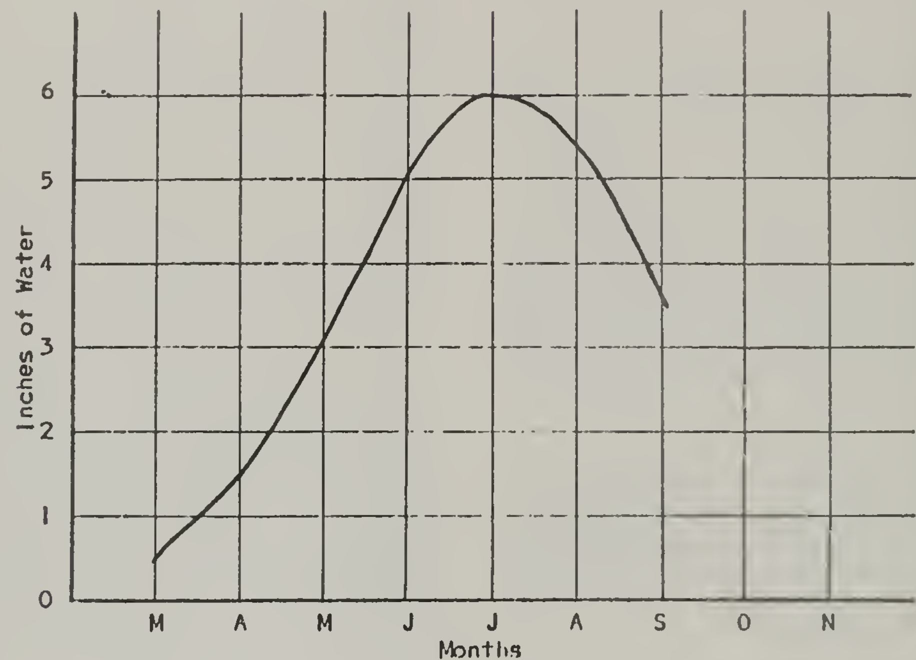


Fig. 1. Potential water use.

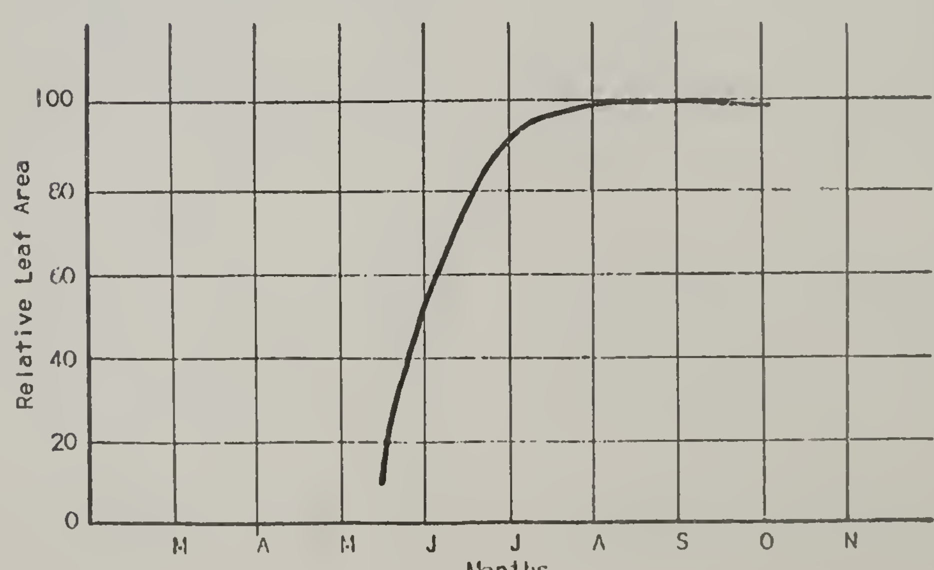


Fig. 2. Probable relative leaf surface area.

D. B. Peters
4/15/57

SEEDLING EMERGENCE CHARACTERISTICS OF SMALL GRAINS AND CORN

It is often helpful to use information concerning the seedling morphology of corn and the small grains in explaining the reasons for specific depth of planting or sowing and in identifying these plants at early stages of growth. The following definitions will help to clarify the terminology in the text to follow:

Auricle - ear-like or claw-like appendage projecting from the collar of the leaf.

Blade - narrow, elongated portion of the leaf (as in grasses, parallel veined and sessile).

Coleoptile - the second botanical leaf of grasses which surrounds the growing point and foliage leaves of seedlings of some plants. It is broken by the growing plant after reaching the soil surface.

Coleorhiza - the sheath enclosing the main root (radicle) of a seedling.

Collar - narrow band of a grass leaf marking the place where the blade and sheath join.

Cotyledon (scutellum) - seed leaf of the embryo which acts as a storage organ in seeds. The first botanical leaf of grasses.

Internode - region of the stem between two successive nodes.

Ligule - small membranous appendage at the collar.

Node - enlarged portion of the stem where leaves and buds arise.

Pubescent - having a covering of hairs.

Seminal roots - seed roots.

Sheath - basal tubular portion of a leaf enwrapping the stem (as in grasses).

Tiller - the shoot of a grass plant originating in the axils of the leaves in the unexpanded portion of the stem.

In corn and oats, emergence is accomplished by means of elongation of the first internode and coleoptile.

Wheat, barley, and rye do not emerge from the soil in the same way as corn, oats, rice, sorghum, sudan grass, bluegrass, timothy, and many other grasses. The first internode does not elongate; but the coleoptile does, and it may attain a length of two inches or more. It ceases growth when the tip is exposed to bright light. Inside the coleoptile, the second internode elongates; and inside the third leaf, the third internode may elongate and the third, fourth, fifth, and subsequent leaves make their appearance successively, one emerging out of another.

The seminal roots consist of the primary root and usually several adventitious roots arising from the unelongated first internode. Whorls of secondary roots develop from the second, third, and fourth internodes which are near the soil surface, as in corn and oats. Under dry conditions, the secondary roots of barley may not develop. In this case, the seminal roots function during the life of the plant.

Axillary buds form at the base of the second and subsequently lower internodes. They become active and develop into tillers. It is possible to have tiller buds arising from the cotyledon of wheat and some other grasses.

If because of deep sowing the coleoptile of wheat, barley, and rye is not able to

reach the soil surface, the second internode and the third leaf elongate. This leaf has only fair penetration (emergence) power, and if it does not reach the surface, the fourth leaf elongates in an attempt to emerge. In general, therefore, wheat, barley, and rye cannot be safely sown as deep as corn and oats. The morphological features and seedling development characteristics of both corn and oats suit these two plants to penetration from lower depths of seeding than wheat, barley, or rye.

The small grains can be identified in the seedling and vegetative stage by means of auricle and ligule characteristics. The auricles of barley are very large and prominent; in rye, they are very small; in common wheat, they are intermediate and pubescent; and in oats, they are absent.

The ligule of all the small grains is membranous, but in barley and rye it is relatively shorter and less prominent than in wheat or oats.

It should be remembered that leaf characteristics vary in varieties and species of the small grains. However, the above description will be helpful for practical field use. (This description is adapted from Agronomy Principles and Practices by L. F. Graber and from unpublished materials used in the beginning crops course at the University of Illinois.)

A. W. Burger
10-29-56

METHODS OF BREEDING NEW FORAGE CROP VARIETIES

Breeding methods used in developing new forage crop varieties are somewhat different from those used in improving corn or small grain. There are good reasons for this difference: First, hybridization cannot be controlled on as large a scale as in corn and, second, uniformity is not so important in forages as in small grains, soybeans, or corn.

Many forage crop varieties that have been released within the past few years or that are being developed are so-called synthetic varieties. By definition a synthetic variety is one that is developed by crossing, compositing, or interplanting two or more desirable selections or clones. The seed of successive generations is then harvested and replanted to constitute advanced generations of that variety.

Another way to define a synthetic variety is to say that it is advanced generations of open-pollinated seed mixtures of a number of selections or hybrids among these desirable selections. The origin of the word synthetic is fairly obvious. By natural intercrossing, the strains (or clones) are synthesized into a new variety. A synthetic variety can be increased through successive seed generations so long as the desired characteristics of the variety are retained.

Considering our present knowledge of plant breeding methods and the fact that most forage species are highly cross-pollinated and highly heterozygous, recombining selected non-inbred plants into synthetic varieties is probably the most effective way to utilize the advantage of their superior characters.

Before any plant or selection is included as a component of a synthetic, it is thoroughly tested. Not only the mother plant (clone), but also its progeny are tested for performance. Selection is based to a large extent on performance of the progeny. Another very important part of testing clones for possible use in these synthetic varieties is determining their combining ability with other clones. By combining ability we mean the relative ability of a particular plant to transmit its desirable characteristics in crosses with other plants. The most desirable number of parent plants to use in developing a synthetic can be determined only by measuring the relative performance of many different synthetics made up of variable numbers of selections. In the past, four or more clones have generally been used in the composition of synthetics.

Advanced generation corn seed, i.e., the seed produced in farmer fields of double-cross corn, is not saved for future planting because subsequent generations are made up in part of many low-yielding and otherwise undesirable plants. Essentially the same thing happens to advanced generation seed of synthetic forage varieties. However, because no other alternative breeding method is currently feasible, the forage breeder must produce synthetic varieties in which the least amount of genetic segregation occurs in the advanced generations. Therefore, advanced generation testing must be conducted before a synthetic is released as a variety.

To illustrate the manner in which synthetics are developed, let us examine the pedigree of Ranger alfalfa. Ranger is a synthetic variety developed by compositing the five strains A-110, A-111, A-116, A-117, and A-119 as tested in a Uniform Alfalfa Nursery Trial. The origin of the strains in this case was inbred lines that were subsequently outcrossed among other selected lines from the Cossack, Turkistan, and Ladak varieties in the proportion of 45, 45, and 10 percent respectively. These strains were developed by Nebraska plant breeders and were composited in 1940 after having been selected and tested for 10 years.

In this selection and testing program, information was obtained on the performance of the individuals themselves and also on the performance of their progeny. In addition to testing for outstanding yield performance, selection for resistance to bacterial wilt was also a primary consideration. Other objectives were winter-hardiness and good seed production.

Ranger is a good variety that has been widely accepted. It has been seeded on more acres than any other single alfalfa variety since the crop was introduced into the United States. By the end of 1955, a total of over 140 million pounds of certified Ranger seed had been produced and planted in this country.

Other synthetic varieties are Narragansett alfalfa, Vernal alfalfa, Lahontan alfalfa, Southland bromegrass, and Itasca timothy. Many experimental strains of forage crops that are currently being tested at the various experiment stations are for ultimate use in new synthetics. As soon as a synthetic is sufficiently tested and proves desirable, it is given a name and released as a variety.

Some of the most desirable synthetics come from selected plants that have very diverse germ plasms. For example, Vernal alfalfa has a very broad genetic base. About 50 percent of its germ plasm is derived from selections out of Cossack that were highly resistant to bacterial wilt; 25 percent from selections out of a diploid "falcata," a wild yellow-flowered stock; 12.5 percent from a single plant selection out of Ladak; and 12.5 percent from a single plant selection from Kansas Common alfalfa.

Forage breeding is complex because of the problems of evaluating breeding materials to fit the many different uses for which species may be grown and the time required for evaluating a single generation of breeding. It is not surprising, therefore, in view of the comparatively short time in which breeding programs have been in progress, that only a few superior strains have been distributed and widely used. However, through the use of basic principles that are becoming available through research, more effective improvement programs will undoubtedly be forthcoming. While recombination of selected plants into synthetic varieties is being used to a considerable extent, this method will undoubtedly be replaced by improved breeding methods as more research is conducted on many forage crops.

C. N. Hittle
12-17-56

AGRONOMY FACTS

GRASS AND LEGUME SEEDING MIXTURES

Forage crop and pasture seeding mixtures need to be varied to meet specific needs, conditions, and climates. The following mixtures and seeding rates are suggested for the latitudes and soil conditions found in Illinois, including drainage. Preference or experience of the farmer may, however, make it desirable to substitute other species. Suggested substitutes are therefore listed below each table (2 to 7).

When a mixture includes several species, there is sometimes a tendency to use too much seed per acre. Table 1 is intended as a guide in determining whether the total seeding rate is too high. It is suggested that a total of not more than 20 units be seeded per acre.

Table 1.--Units per Pound of Seed for Grass and Legume Species*

Grasses	Units/lb.	Legumes	Units/lb.
Bromegrass	1	Alfalfa	1
Timothy	3	Ladino clover	4
Fescue (tall)	1	Alsike clover	2
Orchardgrass	1 1/2	Red clover	1
Reed canarygrass	3/4	Birdsfoot trefoil	1 1/3
Redtop	3	Lespedeza (Korean)	1/2

* An example:	lb./A	Unit/lb.	Units in mixture
Alfalfa	6	1	6
Bromegrass	5	1	5
Timothy	3	3	9
TOTAL	14		20

Table 2.--Suggested Seeding Rates for Pasture Mixtures in Northern Illinois1/

Soil conditions					
Well drained	lb./A	Poorly drained	lb./A	Droughty	lb./A
Alfalfa	6	Alsike clover	3	Alfalfa	6
Bromegrass	5	Ladino	1/4	Bromegrass	5
Timothy	2	Timothy	4	or	
or		or		Birdsfoot trefoil	5
Alfalfa	6	Birdsfoot trefoil	5	Bromegrass	4
Bromegrass	4	Timothy	2	or	
Orchardgrass	3	or		Birdsfoot trefoil	5
or		Reed canarygrass	8	Orchardgrass	4
Birdsfoot trefoil	5	Alsike clover	3		
Bromegrass	4	Ladino clover	1/4	Alfalfa	6
or				Tall fescue	6
Birdsfoot trefoil	5				
Orchardgrass	4				

1/ Suggested substitutions in above mixtures:
1 lb. of red clover for 1 lb. of alfalfa (maximum of 2 lb. of red clover).
1/4 lb. of Ladino clover for 1 lb. of alfalfa (maximum of 1/2 lb. of Ladino).
2 lb. of red clover for 1 lb. of alsike clover.

Table 3.--Suggested Seeding Rates for Hay Mixtures in Northern Illinois[1]

Soil conditions					
Well drained		Poorly drained		Droughty	
	lb./A		lb./A		lb./A
Alfalfa	12	Alsike clover	5	Alfalfa	8
or		Timothy	4	Bromegrass	6
Alfalfa	8	or		or	
Bromegrass	6	Reed canarygrass	8	Alfalfa	8
or		Alsike clover	3	Tall fescue	6
Alfalfa	8				
Bromegrass	4				
Timothy	2				

1/ Suggested substitutions in above mixtures:
1 lb. of red clover for 1 lb. of alfalfa.
2 lb. of red clover for 2 lb. of alsike clover.

Table 4.--Suggested Seeding Rates for Pasture Mixtures in Central Illinois[1]

Soil conditions					
Well drained		Poorly drained		Droughty	
	lb./A		lb./A		lb./A
Alfalfa	6	Alsike clover	3	Alfalfa	6
Bromegrass	5	Ladino clover	1/4	Bromegrass	5
Timothy	2	Timothy	4	or	
or		or		Alfalfa	6
Alfalfa	6	Birdsfoot trefoil	5	Orchardgrass	6
Bromegrass	4	Timothy	2	Birdsfoot trefoil	5
Orchardgrass	3	or		Bromegrass	4
or		Reed canarygrass	8	or	
Alfalfa	6	Alsike clover	3	Birdsfoot trefoil	5
Orchardgrass	6	Ladino clover	1/4	Orchardgrass	4
Timothy	2			or	
or				Alfalfa	6
Birdsfoot trefoil	5			Tall fescue	6
Bromegrass	4				
or					
Birdsfoot trefoil	5				
Orchardgrass	4				

1/ Suggested substitutions in above mixtures:
1 lb. of red clover for 1 lb. of alfalfa (maximum of 2 lb. of red clover)
1/4 lb. of Ladino clover for 1 lb. of alfalfa (maximum of 1/2 lb. of Ladino)
2 lb. of red clover for 1 lb. of alsike.

Table 5.--Suggested Seeding Rates for Hay Mixtures in Central Illinois[1/]

Soil conditions					
Well drained		Poorly drained		Droughty	
	lb./A		lb./A		lb./A
Alfalfa	12	Alsike clover	5	Alfalfa	8
or		Timothy	4	Bromegrass	6
Alfalfa	8	or		or	
Bromegrass	6	Reed canarygrass	8	Alfalfa	8
or		Alsike clover	3	Tall fescue	6
Alfalfa	8			or	
Bromegrass	4			Alfalfa	8
Timothy	2			Orchardgrass	4
or					
Alfalfa	8				
Orchardgrass	3				
Timothy	2				

1/ Suggested substitutions in above mixtures:
1 lb. of red clover for 1 lb. of alfalfa.
2 lb. of red clover for 1 lb. of alsike.

Table 6.--Suggested Seeding Rates for Pasture Mixtures in Southern Illinois[1/]

Soil conditions					
Well drained		Poorly drained		Droughty	
	lb./A		lb./A		lb./A
Alfalfa	6	Alsike clover	2	Alfalfa	6
Orchardgrass	6	Tall fescue	8	Orchardgrass	6
or		Ladino clover	1/2	or	
Alfalfa	6	or		Alfalfa	6
Tall fescue	6	Alsike clover	2	Tall fescue	6
or		Redtop	4		
Tall fescue	8	Ladino clover	1/2		
Ladino clover	1/2	or			
or		Canarygrass	8		
Alfalfa	6	Alsike clover	3		
Bromegrass	6	Ladino clover	1/4		
Timothy	2				
or					
Birdsfoot trefoil	5				
Orchardgrass	4				
or					
Birdsfoot trefoil	5				
Timothy	2				

Korean lespedeza may be added at the rate of 5 lb. per acre to above mixtures except those that include birdsfoot trefoil. Timothy may be added at the rate of 2 lb. per acre to any of above mixtures.

1/ Suggested substitutions in above mixtures for southern Illinois:
1 lb. of red clover for 1 lb. of alfalfa (maximum of 2 lb. of red clover).
1/4 lb. of Ladino clover for 1 lb. of alfalfa (maximum of 1/2 lb. of Ladino).
2 lb. of red clover for 1 lb. of alsike clover.

Table 7.--Suggested Seeding Rates for Hay Mixtures in Southern Illinois 1/

Soil conditions					
Well drained		Poorly drained		Droughty	
	lb./A		lb./A		lb./A
Alfalfa	8	Canarygrass	8	Alfalfa	8
Orchardgrass	6	Alsike clover	4	Orchardgrass	6
or		or		or	
Alfalfa	8	Tall fescue	6	Alfalfa	8
Tall fescue	6	Alsike clover	4	Tall fescue	6
or		or			
Alfalfa	8	Redtop	4		
Brcmegrass	3	Alsike clover	4		
Orchardgrass	3				

Korean lespedeza can be added at the rate of 5 lb. per acre to any of above mixtures.
Timothy can be added at the rate of 2 lb. per acre to any of above mixtures.

1/ Suggested substitutions in above mixtures for southern Illinois:
1 lb. of red clover for 1 lb. of alfalfa.
2 lb. of red clover for 2 lb. of alsike.

J. A. Jackobs
C. N. Hittle
E. C. Spurrier
Department of Agronomy
W. S. Speer
Soil Conservation Service
12/31/56

LESPEDEZA IN ILLINOIS

Lespedeza occupies an important place in our pasture and hay economy because it will grow on many different soils and in many different climates. Its area of adaptation extends from eastern Texas to the Atlantic Ocean, being bounded on the north by a line from southern Iowa to New Jersey, and on the south by the southern limits of the Cotton Belt.

Species. Of the annual species of importance in Illinois, *L. stipulacea* is most widely adapted and includes the following varieties: Korean, Climax, Rowan, Iowa 6, Iowa 48, Iowa 39, and Harbin. Korean is most widely used. *L. striata* is adapted to extreme southern Illinois and farther south and includes Common, Kobe, and Tennessee 76. *L. cuneata* (Sericea) is the most promising of the perennial species, Arlington being the recommended variety.

Characteristics. The drought-enduring lespedezas tolerate soils of low fertility better than do alfalfa and the clovers. Lespedeza tolerates a pH as low as 4.5. The cropping system followed in many areas, with the resultant erosion, has damaged some soils until they will no longer support alfalfa and red clover. Lespedeza has replaced the clover. Although it may be somewhat less valuable as hay, clean, early-cut, properly cured lespedeza hay compares favorably with alfalfa. Analyses of Korean at Dixon Springs indicate 10-11 percent protein compared with 12-13 percent for high-quality alfalfa and 9.5 percent for perennial lespedeza. Lespedeza contains about one-fourth as much Ca, twice as much P, and about the same amount of K as alfalfa. This may partially account for its tolerance to acidity and its excellent response to phosphate. Kobe and Climax have similar areas of adaptation and both mature two weeks later than Korean.

Plants of annual lespedeza are fine-stemmed and have short branches with numerous small trifoliate leaves. Growth is erect or spreading, depending on thickness of stand. Plants range from 5 to 36 inches high (average, 15 inches) and have a medium-deep, fibrous root system. Flowers are self-fertilized and of two kinds: blue to purple and the more numerous inconspicuous flowers without petals. Varieties of common lespedeza set seed in the leaf axils directly along the stems, whereas varieties of Korean are borne in clusters at the tip of the branches, developing from the leaf axils.

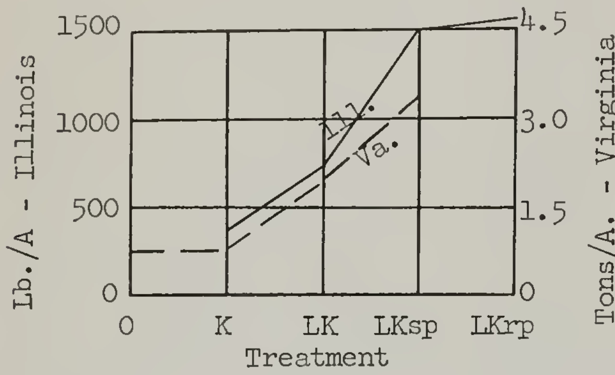
Day length affects the seed set of lespedezas. Under a long daylight period of 17 hours, seed is not produced. Therefore, natural reseeding of the annual lespedezas occurs only under shorter day lengths. Characteristics of the unhulled seed are helpful in distinguishing varieties of lespedeza.

The perennial lespedezas comprise most of the known species, but they have not been widely accepted because they are slow and difficult to establish and the plants are coarse. Only Sericea has proved of economic value as a hay and pasture crop. Although it resembles alfalfa in some respects, it is readily distinguished by its small leaves and inconspicuous flowers, which may be white, yellow, or purple. The plants are grayish-green and have a single crown that may produce several dozen stems that will grow five feet high if left uncut. In the spring, the buds originate from the crown, but the regrowth after the first cutting originates from buds on the stems. This characteristic distinguishes lespedeza from alfalfa.

Culture. Lespedeza responds remarkably well to soil treatment. There is a

close correlation between yields of lespedeza hay for similar soil treatment in Illinois and Virginia.

Figure 1. Effect of Fertility on Yields of Korean Hay



It is important to choose an adapted variety and inoculate the seed. The annuals can be broadcast in small grain in March and April. Whether seeded alone or in mixtures (without a nurse crop), they require a good seedbed and should be seeded about the time spring oats are sown. Seeding rates vary from 5 pounds in "shotgun" mixtures to 15 to 20 pounds when seeded alone. Disking early in the spring increases hay yields where self-feeding is desired--additional seed is of little value. By the third year naturally reseeded areas are usually very weedy. If areas are clipped to control weeds, care must be taken not to clip off the tips of plants or production will be lowered. If natural reseeding is desired, hay must be cut early (first bloom) and left reasonably high, since reseeding occurs from the second growth.

The perennial is best seeded alone (lack of competition favors establishment) or on a prepared seedbed in the spring, after danger of frost, at 40 pounds per acre. Weeds should be clipped the first year. No hay or grazing can be expected the first year. A hay or seed crop can be removed the second year and either two hay crops or a hay crop and a seed crop thereafter.

Uses. The annual lespedezas can be used in many ways:

1. For temporary pasture to relieve or supplement permanent pastures from July to October. Production of 100 pounds of beef per acre is common.

2. For seeding in small grain to provide a highly nutritious hay and grazing crop, following removal of the small grain. Good management frequently requires the use of small grain in conjunction with the annual lespedezas. The average hay yield is same as red clover--one ton per acre.

3. As part of a "shotgun" mixture of adapted legumes to provide insurance in areas where clover fails.

4. To extend the life of severely thinned stands of other legumes. Normally a uniform broadcast or drilled seeding of 10 to 14 pounds per acre will extend the productive life of these pasture or hay crops at least a year.

5. As a legume that can be maintained indefinitely by natural reseeding in permanent pastures. Investigations indicate that proper grazing management is the determining factor.

6. As a legume that can be used for soils where the fertility level will not support clover and alfalfa. Success with lespedeza has induced many farmers to reestablish other legumes.

Sericea lespedeza is used advantageously south of Route 50 in Illinois:

1. On soils too poor to establish other perennial legumes.

2. Because it withstands closer grazing than some of the other widely used perennials. This is a fortunate circumstance, because young Sericea plants contain only one-fourth as much tannin as older plants.

3. Because its mulching habit makes it one of the strongest soil improving and conserving crops. At Dixon Springs, on a field seeded in 1953 and used only for producing seed, 15 tons of oven-dry mulch per acre have accumulated in four years (1953-1957).

4. Because it is comparable to alfalfa in feeding trials. At Dixon Springs, in pelleted lamb fattening rations containing up to 55 percent hay, results with alfalfa and Sericea were comparable (A.D.G.-4 lb.), although alfalfa had 12.71 percent protein vs. 9.21 percent for Sericea.

5. Because it is capable of maintaining itself longer than most of the other perennial legumes. Stands as old as twenty years are reported; however, management will be the main factor in determining length of life.

6. Because it is not so subject to diseases and insect damage as are some of the other perennials. Dodder, its worst enemy, may reduce the quality of the seed crop.

7. Because it is not so subject to heaving as alfalfa. It has a more fibrous root system in the surface soil in conjunction with its deep-penetrating top root, and it accumulates a mulch that stays put better than other hay crops because two to three inches of stubble is left in cutting.

George McKibben
4/8/57

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

AGRONOMY FACTS

F-26

TIMOTHY (PHLEUM PRATENSE)

Timothy is one of the easiest grasses to grow. The seed is cheap and sows readily. Seeding failures are uncommon. Hay standards have been based on timothy, and few grass hays are superior to it in quality. In pastures timothy is a valuable component in seeding mixtures because it becomes established readily and furnishes grazing while a grass like smooth brome is becoming established. It also is one of our most palatable pasture grasses.

Timothy is not equal to other grasses in certain respects. It is more sensitive to moisture deficiency than smooth brome or orchardgrass, and it produces less aftermath than these grasses. It requires better soil drainage than tall fescue and redtop. It is also shorter-lived than these grasses, especially when grazed.

Timothy originated in Europe and was introduced to this country in colonial times. Since that time it has been our most extensively seeded forage grass. A short-lived perennial that grows well in cool, humid regions, it is adapted throughout Illinois. Accumulation of carbohydrates causes one or two of the lower internodes of the timothy stem to swell. The bulb-like structure that forms is called a "haplocorm" and is not found in our other forage grasses. The individual timothy shoot is biennial, but because new shoots develop each year from the base of existing shoots, the plant persists as a perennial.

The seed of timothy is very small (1,100,000 to 1,300,000 seeds per pound). When sown it should not be covered more than $\frac{1}{2}$ inch deep. It may be planted in the spring or fall, depending on the location in the state and the method of seeding. With a companion crop of winter wheat, it should be sowed in the fall with the wheat. When seeded in the spring, it should be broadcast on the surface of the frozen ground. In northern Illinois it can be seeded at the same time as a spring cereal. Spring seedings in southern Illinois are more likely to fail than those made in late summer.

Timothy is seldom seeded alone, usually being mixed with one or more legumes. It benefits indirectly from the nitrogen fixed by the legume. If it is grown alone, nitrogen fertilizer must be applied if it is to be as productive as when grown with a legume. Red clover is the legume that has been most widely used with timothy, although recently timothy has been used more widely with alfalfa. Alsike clover also is commonly used with timothy. When timothy is seeded as the only grass in a mixture with legumes, about four pounds per acre should be seeded. If it is seeded with another grass in mixture with legumes, about two pounds per acre will be needed.

The best time to cut timothy for hay is in the early-bloom stage. At that stage about 50 percent of the total weight is leaves and the protein is about 1.5 percentage points higher than at the stage just past full bloom. The quality of the hay declines rapidly after the full-bloom stage.

When timothy is saved for seed, yields generally vary from 140 to 320 pounds per acre. The seed can be combined directly after 90 percent of the heads have turned brown and the ripest heads have begun to shatter. Higher quality seed results, however, if the crop is cut with a binder, shocked, and threshed with a stationary thresher or combine.

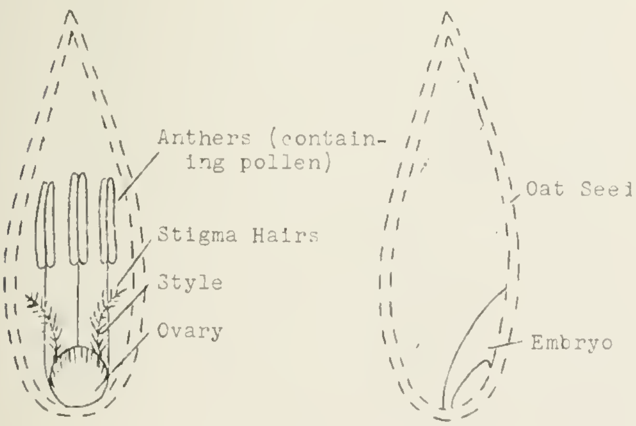
Nearly all of the timothy seeded in Illinois is the ordinary, unimproved type. Several improved varieties have been developed, but none have been used widely. Little or no seed of the improved varieties is available commercially.

J. A. Jackobs
2/18/57

DO WE HAVE HYBRID OATS?????

Because of the tremendous interest in hybrid corn in recent years, many farmers have begun to ask questions about "hybrid" oats. Since hybrid corn has increased yields of corn so much, they wonder whether the same thing can be done with oats. This fact sheet is being prepared to explain just why we do not have "hybrid" oats and why we will probably never have them.

To make this explanation clear, we need to go into the details of how pollination takes place in oats. We speak of oats as being a self-pollinated crop, whereas corn is cross-pollinated. In fact, Nature has provided a way to insure self-pollination in oats by having the male and female parts of the oat plant located in the same enclosure, as shown in the following diagram:



This diagram shows what an oat seed looks like before pollination takes place compared with the mature seed. In each oat floret (young seed), before pollination takes place there are three anthers. The anthers are the male organs of the oat plant that bear the pollen. Just below the anthers are located two styles that contain numerous little stigma hairs. At the base of the style is the ovary. The female parts (egg) of the young seed are located within this ovary.

When the pollen is mature inside the anthers, they split along the long axis and let the pollen drop down onto the stigma hairs. The pollen then germinates on the hairs and sends out pollen tubes that grow completely through the stigma hair and style and into the ovary. The tube enters the ovary and discharges its male cells, which unite with the egg in the ovary. Soon after this union, the cells begin to divide and grow, causing the ovary to enlarge to form the mature oat seed.

It is interesting to note the speed at which all this takes place. Within five minutes after the pollen drops on the stigma hair, it germinates and the tube begins to grow. It takes the tube about 20 minutes to reach the ovary. Union of the male and female is completed about 10 hours after pollination, and the cells begin to divide in about 13 hours. Approximately 30 days from the time of pollination, the oat seed is completely mature.

From this brief description, you can see why the oat plant seldom has a chance to be cross-pollinated. In corn the male parts (pollen) are located in the tassel, whereas the female parts are located in the ear shoot. This makes it simple to remove the tassel containing the male parts to provide an opportunity for controlled cross-pollination.

Cross-pollination can also be accomplished in oats, but it is a very delicate and time-consuming task that has to be done by hand. The process involves opening the young floret (seed) by hand before pollination takes place, removing the 3 anthers (male parts), and closing the floret again without injuring it. One to two days later the floret has to be opened again and anthers from another oat plant containing ripe pollen must be placed in the floret to complete the cross. The floret is then closed.

Each of these steps requires a considerable amount of skill and must be done without injuring the young seed if good results are to be obtained. Even the best operators will obtain only about one seed for every 10 attempts. It has been estimated that approximately one hour's work is required to obtain one crossed seed. You can readily see that it would be impossible to obtain enough crossed seed for even one acre of the more than three million acres of oats planted in Illinois each year. It is for this reason that there is no hope of having "hybrid" oats.

Although there is no such thing as "hybrid" oats, practically all oat varieties used today have resulted from the crossing of one or more varieties. However, this crossing is not done for the purpose of capturing "hybrid" vigor. The crossing in oats has instead involved making a cross between different varieties each of which contains some desirable characteristics that the other does not have. One or more plants are then selected out of the cross that possess the desirable characteristics of both parent varieties. This plant is then allowed to self-pollinate, and the seed is increased over a period of years to produce a new variety. Once the variety is produced, it will remain reasonably pure unless it becomes mixed with some other variety.

C. M. Brown
10-8-56

INTERSPECIFIC CROSSES AND OAT BREEDING

Oat breeders have constantly searched for sources of disease-resistant stocks to use in combating the many diseases that cause a considerable amount of damage to oats from year to year. Not only many different diseases attack this crop, but often many different races or strains of the same disease. For example, over 80 different races of the leaf rust fungus of oats have been identified. New races of the various diseases originate from crossings between existing races and from mutations; thus the number continues to increase. For this reason it is difficult, if not impossible, to produce oat varieties that are resistant to all races of all diseases. However, oat breeders continue to search in the hope that the ideal variety, from the standpoint of disease resistance, will be developed.

In recent years the search for resistance has led to the use of other species that are somewhat distantly related to our common oats, Avena sativa. One such species, Avena strigosa, has been found that carries resistance to most of the races of rust as well as to some of the other diseases. Oat breeders immediately attempted to use this new species in their oat breeding programs. But when they tried to cross it with our common oat varieties, the results were very unpromising. In the first place, it was all but impossible to make the cross and, when they did succeed, the few seeds that were obtained produced plants that were completely sterile.

Microscopic examination showed that Avena strigosa had only 7 pairs of chromosomes, whereas our common oats have 21 pairs. Apparently the two species were not closely enough related in chromosome number to produce fertile progeny when crossed. This made it appear impossible to use this new and badly needed source of disease resistance.

Realizing the importance of capturing this new type of disease resistance, breeders began to search for ways to use it. The new search led to the use of still another species, Avena abyssinica, that was found to be a little more closely related to common oats than the Avena strigosa. Avena abyssinica, instead of having 7 pairs of chromosomes like Avena strigosa or 21 pairs like common oats, was found to have 14 pairs.

Whereas it had been all but impossible to cross Avena strigosa with common oats, it was rather easy to cross Avena strigosa with the Avena abyssinica species. But again all the plants that resulted from this cross proved to be completely sterile. Microscopic examination showed that each cell of the sterile plants contained 21 chromosomes, 14 having come from the Avena abyssinica parent and 7 from the Avena strigosa parent. But instead of occurring in pairs, as in normal plants, each of the 21 chromosomes occurred individually, causing complete sterility.

It was obvious from these observations that, if each chromosome could be duplicated or doubled, the resulting plants would have not 21 individual chromosomes but 21 pairs of chromosomes, as our common oats have. The doubling was later accomplished by treating plants containing 21 single chromosomes with a chemical called colchicine, which caused each chromosome to duplicate itself. In this way a new type of oat was produced that contained 21 pairs of chromosomes like our common oats. In addition to being fertile, this new oat could be crossed with common oats, since both had the same number of chromosomes. In this roundabout way the disease resistance of Avena strigosa, with only 7 pairs of chromosomes, could be transferred to our common oat varieties, which contain 21 pairs of chromosomes.

Although we are not far enough along to know just what will come of this type of breeding, it does appear to be a promising approach to the future. We hope that other characteristics, such as drought and heat resistance, can be transferred from some of the related species to common oats in this same way.

The following diagram shows this method of breeding:

Avena abyssinica (14 II) x Avena strigosa (7 II)

Sterile oat plant (21 I)

+

Colchicine treatment to double chromosomes

=

Fertile oat plant (21 II)

x

Common oat variety (21 II)

New disease-resistant oat variety (21 II)

I = single chromosome
II = pair of chromosomes

C. M. Brown
11-12-56

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

AGRONOMY FACTS

S-7

VARIABILITY IN CHEMICAL COMPOSITION OF SEED FROM DIFFERENT PORTIONS OF THE SOYBEAN PLANT

In breeding soybean varieties for improved industrial value, the method of taking chemical samples from portions of a single plant or from plants within a nursery plot is important. Soybean seed from different parts of plants of several varieties and types have been analyzed for oil content and other characteristics to determine how composition varies within the plant and between plants.

Seeds from the lower half of Lincoln soybean plants have been found to contain about one-half percent more oil and one percent less protein than those from the upper half. This is characteristic of varieties of indeterminate growth type, such as Lincoln and Earlyana. Seeds from the terminal node may contain as much as six percent less oil than those from nodes in the bottom half of the plant.

Plants of determinate varieties, such as Hawkeye and Richland, have a narrow range in oil content. Seeds from the terminal nodes of these plants have only one to two percent less oil than the highest ones found on the plant. One variety, Jogun, produced the highest oil content in seeds from the terminal raceme. This characteristic has not been observed in any other variety.

Despite variability between nodes, all plants of one variety are similar in pattern of oil content. The distribution of oil in the seeds on branches is similar to that on the main stem. Seeds produced near the tip of a long raceme have a lower oil content than those produced farther down. The seed in the tip position in the pod has the highest oil and lowest protein content, but the difference within pods is not very large.

Seeds produced on the upper nodes of a plant are generally smaller than those on the central and lower portions. In three-seeded pods, the heaviest seed is in the middle. The location of pods on the plant has a much greater influence on size of the seed and its chemical composition than position of the seed in the pod.

In all varieties of soybeans, the oil content of seeds from different nodes of a single plant varies substantially. Furthermore, the high-yielding plants within a drilled row produce seed with a higher oil content than the low-yielding plants (Figure 1). Selection of single plants for genetically high oil content of their seeds from a segregating population should be made only on plants with comparable yields and grown under similar environmental conditions. Disregarding these variations in plants will reduce the effectiveness of selection procedures based on chemical analysis.

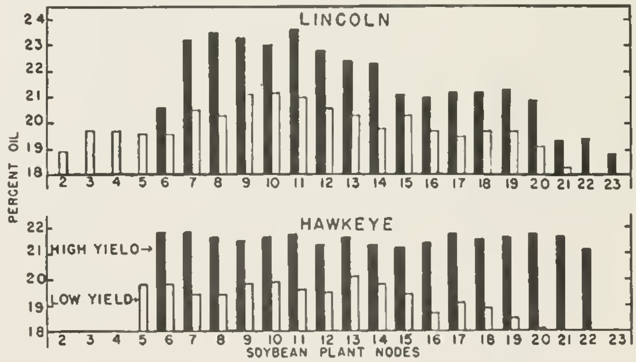


Figure 1.--Oil content of high and low yielding soybean plants by nodes for the varieties Lincoln and Hawkeye.

F. I. Collins, Chemist
U. S. Dept. of Agriculture
12-3-56

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

AGRONOMY FACTS

S-8

STEPS IN DEVELOPING A NEW SOYBEAN VARIETY

Soybeans are native to eastern Asia, where they have been cultivated for over 5,000 years. They were first introduced into the United States on a large scale about 60 years ago. Most early varieties were produced as selections from these introduced strains. Such varieties as Illini, Dunfield, Richland, Manchu, Patoka, and the hay types, Wilson and Virginia, originated in this way. The first soybean variety for Illinois developed by selection following crossing was Chief, selected from the cross Illini x Manchu and released by the Illinois Agricultural Experiment Station in 1940. All presently recommended varieties in Illinois have been selected from crosses.

Soybeans are a naturally self-pollinated crop (less than 1 percent of the flowers are fertilized with pollen carried by insects from other plants), and therefore breeding methods are essentially the same as those used for wheat and oats. The first step in developing an improved variety is choosing the parents to be used in crossing. The U. S. Regional Soybean Laboratory, with headquarters located at the University of Illinois, has a "Germ Plasm Bank" of about 3,000 strains collected mainly from Manchuria, China, and Japan. Most of these strains are poor in general agronomic desirability, but many have some outstanding trait, such as disease resistance or high oil content, that breeders can use in crosses to improve soybean strains for commercial growing. These plant introductions are evaluated and made available to soybean breeders throughout the country.

The next step is making the actual cross-pollination. Before natural pollination occurs, the small flower bud must be opened and the pollen-bearing stamens removed with a small pointed pair of forceps. Pollen is then applied from an open flower of another variety with which the cross is to be made. Many such pollinations are not successful, but under good conditions about one seed is obtained for every two or three hand pollinations.

Sometimes backcrossing is done in cases where it is desired to transfer such traits as disease resistance or seed coat color, which are simply inherited and easily evaluated, to an otherwise excellent variety. The variety is crossed to any strain with the desired trait, the plant that is produced is "back-crossed" to the variety, and this process is repeated for several generations.

The final step in producing a new variety is testing, selecting, and retesting the many different strains obtained from each cross. In the second generation (F_2) following crossing, individual plants of the segregating population are selected for such traits as disease resistance, seed color, and resistance to lodging and shattering. These plants are classified into maturity groups, and the progeny of each plant is planted in a row at a location suitable for its maturity. In the F_3 generation and again in the F_4, the best appearing plants from the best appearing rows are selected. Strains from F_3 or F_4 plants are usually sufficiently uniform for preliminary yield testing in replicated plots at several locations in the state.

In addition to agronomic evaluation, chemical evaluation is carried on concurrently so that high-yielding lines have also been evaluated for protein and oil content and other characteristics that make the variety valuable to industry. After a year or two of testing and possible reselection, the best strains are entered in regional Preliminary Tests

(Continued)

and grown at one or two locations in several states to more thoroughly evaluate their potential performance. The best strains from the Preliminary Tests are entered in the regional Uniform Tests, which are grown at 15 to 25 locations throughout the Soybean Belt.

These tests show the reaction of the strains to diverse soil, fertility, and cultural conditions, and their resistance to lodging and shattering under widely different rainfall and drouth conditions. Detailed information is also obtained on resistance to diseases occurring in the various sections of the country. Testing over a wide geographical range makes it possible to select strains with wide areas of adaptation, and the relative potential performance of strains in any one area can be estimated in a shorter time.

Strains that perform best under the varied conditions imposed by the Uniform Tests are considered for simultaneous increase and release by interested state experiment stations. Strains are frequently in as many as 100 tests over three to six years before being recommended to farmers. All presently recommended soybean varieties in Illinois have undergone this method of evaluation prior to their recommendation. A report of the performance of these recommended varieties appears in Illinois Agricultural Experiment Station Circular 760.

The table below, based on data from the Cooperative Crop Reporting Service, shows the percentage of the total soybean acreage in Illinois that each soybean variety occupies. Lincoln was released in 1944 and, partly because of its higher yield and superior lodging resistance, rapidly replaced other varieties of comparable maturity. Now Lincoln has been largely replaced by superior varieties more recently released.

No new variety is released for commercial production unless it has been proved, through extensive testing, to be superior in one or more characters to existing varieties it is designed to replace. It takes about ten years to produce a soybean variety from the initial cross to the time it is made available to farmers.

Variety development has made possible the establishment and rapid expansion of the soybean as a grain crop in the Midwest. Present breeding work will aid in further expanding the crop by increasing production efficiency and reducing the threat of new diseases.

SOYBEAN VARIETIES GROWN IN ILLINOIS

	Percent of Total Acreage												
	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
Hawkeye					2.0	13.2	29.2	35.7	33.2	37.3	37.1	42.6	39.4
Adams							1.5	2.2	5.5	9.4	13.6	11.8	14.7
Clark										.1	1.5	6.8	13.2
Lincoln	1.1	10.7	49.6	66.5	68.5	54.1	41.0	32.2	26.9	26.3	19.5	17.2	11.4
Harosoy											1.5	4.3	10.8
Wabash						1.8	4.5	9.0	9.0	6.0	6.7	6.1	4.2
Other	98.9	89.3	50.4	33.5	29.5	30.9	23.8	20.9	25.4	20.9	20.1	11.2	6.3

R. L. Bernard, Research Agronomist
J. L. Cartter, Research Agronomist
Agricultural Research Service
U. S. Department of Agriculture

2-25-57

SHOULD NITROGEN BE PLOWED UNDER WITH CORNSTALKS?

Many farmers are worrying more about handling last year's cornstalks than about growing next year's crop. Their concern has been brought about by the many stories suggesting that farmers plow under nitrogen with cornstalks on the theory that it will speed up rotting and leave more humus from the stalks. Unfortunately, research data relating to this question have generally been overlooked.

Most soil scientists who have either carried on research on this subject or studied the results of such research agree that under most conditions it is not necessary to add nitrogen to cornstalks. Under practical conditions the soil supplies the small amount of additional nitrogen the microbes need for bringing about the decay of cornstalks, and adding more nitrogen will not cause the bacteria to work any faster. Furthermore, these scientists tell us that there is no practical reason for speeding up the decay of cornstalks.

The results of this research also point out that adding nitrogen to cornstalks or other low-nitrogen crop residues, such as straw, to increase the ratio of nitrogen to carbon does not produce more humus from these residues. According to the U. S. Department of Agriculture Experiment Station at Beltsville, Maryland, the amount of humus resulting from a ton of crop residues depends on the composition of the residues, and not on the ratio of nitrogen to carbon.

When the organic matter is low in nitrogen, as are cornstalks and straw, the microbes that bring about decay are not able to get enough nitrogen from these materials and they have to make up this shortage by taking some nitrogen from the supply in the soil. The nitrogen needed by the microbes in addition to that supplied by the cornstalks or straw usually amounts to 10 to 20 pounds per ton of these materials. But under field conditions the soil can usually supply this extra nitrogen. The nitrogen from the cornstalks as well as from the soil is temporarily tied up in the bodies of the microbes and is eventually released to the soil again after the microbes die and decompose.

The fact that microbes must take nitrogen from the soil does not necessarily mean that the crop that follows will suffer from competition for nitrogen. A soil that has grown good crops of legumes is usually able to supply plenty of nitrogen for both the microbes and the corn crop. Then, too, the microbes and the growing crop usually do not need nitrogen at the same time. Often the microbes will have caused most of the stalks or straw to decay before the corn crop has grown enough to require much nitrogen. Usually most of the stalks have rotted by the first part of July. An experiment at the Ohio Agricultural Experiment Station showed that corn planted on May 20 needed only three pounds of nitrogen during the first month and only 15 pounds during the second month.

Results of studies on some of the soil experiment fields in Illinois indicate that the microbes that cause crop residues to decay are not competing unfavorably with the growing crop for nitrogen.

There are, of course, some special cases where the microbes compete with the growing crop for nitrogen and a nitrogen fertilizer needs to be added to feed the crop. Such a situation might develop where rye has been allowed to grow late in the spring and reach a stage of growth where it is low in nitrogen. When this rye is plowed under just before corn is planted, there is likely to be some competition for nitrogen between the soil microbes and the corn crop. The microbes have the advantage in this

competition. They always manage to eat at the first table. When the corn crop begins to need nitrogen, the microbes may have used up much of the supply of available nitrogen, and it will not be released from their bodies in time to feed the crop.

Of course, nitrogen may not be the only cause of low yields of corn following late-plowed rye. In a dry spring the rye may use too much soil moisture, and as a result germination and early growth of the corn will suffer. Another place where microbes may compete with the growing crop for nitrogen is where a heavy straw growth is plowed under just before wheat is seeded. Here the competition is likely to handicap the wheat unless extra nitrogen is provided.

Apply Nitrogen to Increase Yield - Not to Rot Residues

Nitrogen fertilizers should be used on soils that are low in nitrogen to increase crop yields rather than on low-nitrogen crop residues, like cornstalks or straw, in the hope of speeding up decay or saving more humus from these materials. These were the conclusions of W. B. Bartholomew of Iowa State College of Agriculture after a thorough study of the research relating to this question.

Bartholomew points out that there is plenty of field evidence to show the value of adding nitrogen to increase crop yields on soils that are deficient in this plant food. On the other hand, there is little field evidence to support the use of nitrogen in hastening the decay of crop residues or in saving humus. In summarizing this research, Bartholomew has this to say about the use of nitrogen in hastening the decay of crop residue:

"Although nitrogen has been shown to speed up the early stages of decomposition--first month or six weeks--of non-leguminous residues, only a rather small quantity of nitrogen is required to obtain a maximum speed of decay. Increasingly more rapid rates of decomposition do not result from the addition of higher amounts of nitrogen.

"Generally 10 to 20 pounds of nitrogen per ton of residues results in the maximum rate of decay. Rates of nitrogen above these amounts generally have no stimulating effect on decomposition, and in some instances have actually slowed down the decomposition process. Sufficient nitrogen to result in near maximum rates of residue decomposition under field conditions is usually made available from the soil during the decaying process."

Tests made so far show little evidence that applying nitrogen to low-nitrogen crop residues such as straw and stalks will increase the amount of humus. In summarizing the research on this question, Bartholomew has this to say:

"In ten decomposition studies which had been continued for more than one year, three found nitrogen to have no measurable influence on the extent of decomposition, three found nitrogen to slow the rate of decomposition or to conserve carbon, and four found nitrogen to increase the rate of carbon loss. In general, the high rates of nitrogen addition have been most frequently associated with the slower rates of decomposition.

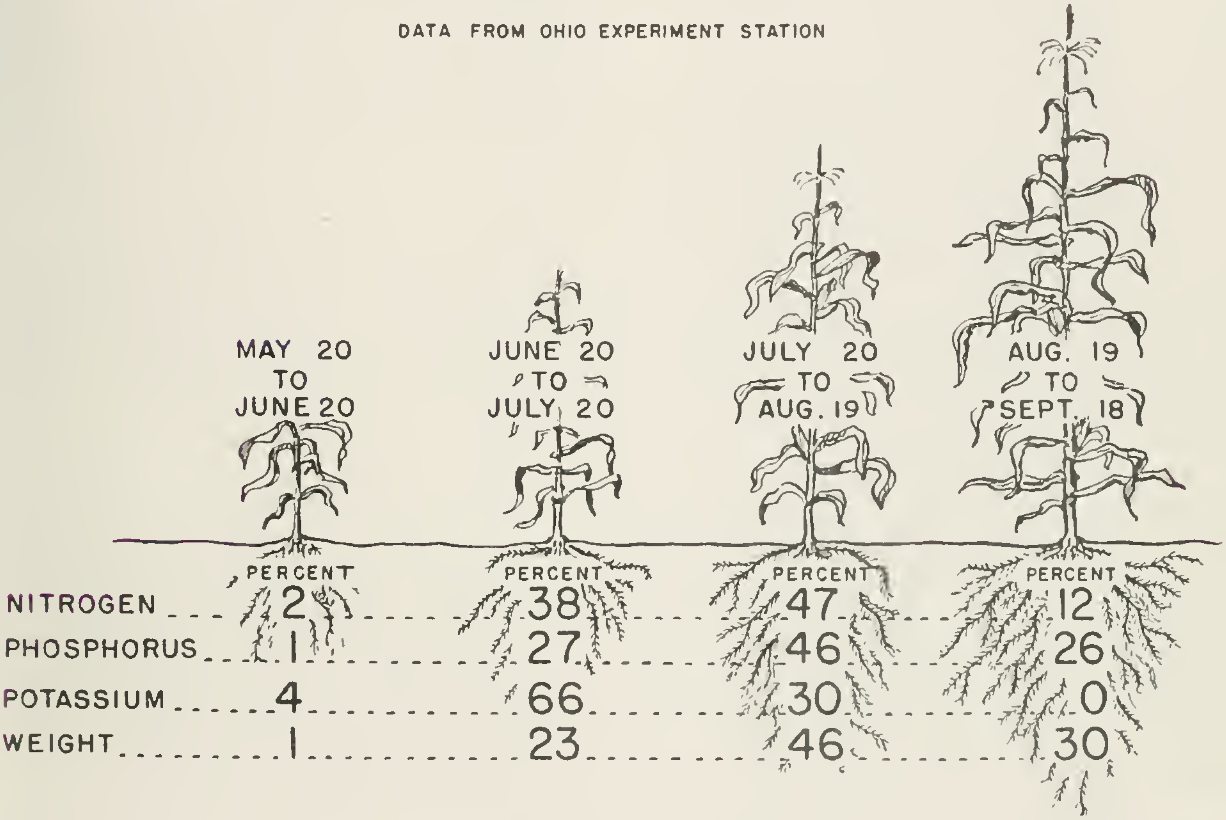
"From the data at hand, it appears that under some conditions of decomposition and particularly if high rates of nitrogen addition are made, slightly more organic matter may frequently result where nitrogen is applied to crop residues than where it is not added. . . The economy of the practice under normal field conditions, however, needs careful consideration. The organic carbon saved per unit of nitrogen applied is often very low."

Second-year corn often needs extra nitrogen. If you plow nitrogen under for second-year corn, you will probably plow it under with cornstalks. But plow the nitrogen under to feed the second-year corn crop, and do not worry about last year's cornstalks or soil organisms. They will both take care of themselves.

C. M. Linsley
10-22-56

PLANT FOOD ABSORBED BY CORN DURING DIFFERENT PERIODS OF GROWTH

DATA FROM OHIO EXPERIMENT STATION



The corn plant produces almost half of its total weight during one month of the growing season. This is one of the interesting facts found in a research project carried on jointly by the Ohio Agricultural Experiment Station and the United States Department of Agriculture. In this experiment they measured not only the amount of growth produced, but the amount of plant food absorbed during different periods.

The yield of corn in this experiment was approximately 100 bushels, and the total weight of dry matter (above ground) was 12,387 pounds. Weights of the various parts of the plant at maturity were as follows:

Leaves............	1,531 pounds
Stems.............	3,462 pounds
Husks.............	1,179 pounds
Cobs..............	989 pounds
Grain.............	5,723 pounds
Total..........	12,884 pounds

The weight of the roots was not determined in this experiment. However, corn root studies made by Fehrenbacher and Snider at the Illinois Experiment Station indicated that the root growth for a 100-bushel crop of corn would amount to about 5,350 pounds.

In the Ohio experiment the 100-bushel crop of corn used 144 pounds of nitrogen, 30 pounds of phosphorus, and 98 pounds

of potassium. The amount of potassium in the corn plant actually reached 113 pounds. This high point was reached in August. After about August 25 the amount gradually decreased because of loss of potassium from the plant.

The illustration on the other side shows the percentage of nitrogen, phosphorus, and potassium absorbed and the growth produced each month during the four-month growing period.

During the first month after planting, the corn crop took up only 2 percent of the total nitrogen absorbed during the entire growing season. Two percent of the 144 pounds of total nitrogen would amount to only about three pounds. By July 1 the corn plant had taken up 15 pounds of nitrogen per acre. The corn crop therefore does not have to have a large amount of nitrogen available during the first month to six weeks after planting.

During the third month, however--from July 20 to August 19--the plants took up about 67 pounds of nitrogen, or almost half of the total requirement. The greatest intake of nitrogen occurred during the last few days of July, when the plants took up an average of four pounds per acre per day. This heavy requirement occurred about tasseling and silking time.

The plants absorbed only 1 percent of phosphorus during the first month. But during the third month--from July 20 to August 19--they took up almost half of their total requirement for phosphorus.

It is interesting to note that corn plants take up potassium much earlier than either nitrogen or phosphorus. In the Ohio tests they took up 66 percent of their potassium requirement during the second month. The maximum rate of potassium intake occurred from July 5 to July 17, when an average of 3.2 pounds per acre entered the plant. The potassium reached its maximum about three weeks after silking. After that time there was an actual loss, largely from the leaves and stems. Potassium may be partly washed from the leaves and stems back into the soil, or it may move back into the soil through the root system.

Results of this study show that, if high yields are to be produced, the soil has to be able to supply large amounts of plant food to the corn crop during the period of rapid growth. This has always been the goal of the Illinois Soil Program, and here is where the soil test comes in.

The soil tests will tell whether limestone, phosphate, and potash are needed and how much of each is needed per acre to supply the crop with plenty of plant foods during the period of most rapid growth. Testing to find out whether your soil can supply your corn crop with plenty of nitrogen when it needs it is neither so simple nor so satisfactory as testing for other elements. But previous cropping and soil treatment practices can be used as a guide in estimating nitrogen needs.

C. M. Linsley
1-28-57

SOIL FERTILITY AND TESTING

AGRONOMY FACTS

SF-47

THE FUNCTION OF ORGANIC MATTER IN CROP PRODUCTION

One of the factors that contributes most to the high fertility of Illinois soils is their high content of organic matter. Organic matter supplies nutrient elements for plant growth and also changes the physical and mechanical properties of the soil, such as structure, base-exchange capacity, moisture-holding capacity, and color. It exerts an influence on soil properties far out of proportion to its percentage by weight.

Organic matter contributes to plant growth mainly through its effect on the physical, chemical, and biological properties of the soil. It performs the following functions:

1. It serves as a reservoir of chemical elements that are essential to plant growth. Most of the soil nitrogen occurs in organic combination; generally only a small fraction, usually from 1 to 3 percent, occurs in inorganic forms at any one time. Also, from 10 to 75 percent of the total soil phosphorus is organic. Significant quantities of other nutrient elements, such as sulfur, are associated in some way with organic matter.

2. Aeration, water-holding capacity, and permeability are all favorably affected by organic matter. The frequent addition of easily decomposable organic residues causes the synthesis of complex organic compounds that bind soil particles into structural units called aggregates. These aggregates help to maintain a loose, open granular condition. Water is then better able to enter and percolate downward through the soil.

   The roots of plants need a continual supply of oxygen in order to respire and grow. Large pores make it easy for the soil to absorb oxygen from the atmosphere and to expel carbon dioxide.

3. Some elements that are held in inorganic forms become more available through the influence of organic matter. During the decomposition of plant residues, certain acids (particularly carbonic acid) are formed that dissolve soil minerals and make the nutrients in the minerals more available to the plant.

4. Organic matter increases the ability of the soil to resist erosion. First, it helps increase water-holding capacity. Of equal importance is its effect in promoting soil granulation and thus maintaining large pores through which water can enter and percolate downward. In a granular soil the groups of particles are not so easily carried along by moving water. Loss of pore space in long-cultivated soils is mainly a loss of the larger pore spaces. As a result, the soil becomes dense and compact, water enters slowly, and surface runoff increases.

5. The organic fraction has a profound effect on the structure of soils. The deterioration of structure that accompanies intensive tillage is usually less rapid in soils that have a high organic matter content. When the organic matter is depleted, soils tend to become hard, compact, and cloddy. Seedbed preparation and tillage operations are easier to carry out and are more effective when organic matter is plentiful.

6. Organic matter serves as a source of energy for the growth of soil organisms. Since most soil organisms require complex organic substrates to meet their nutritional needs,

these organisms diminish in number as the supply of organic matter becomes depleted.

The role played by the soil fauna and microflora in soil fertility has not been completely elaborated, but the functions they perform are multiple and varied. For instance, earthworms may be important agents in producing good soil structure. They construct extensive channels through the soil which serve not only to loosen the soil, but to improve drainage and aeration. Earthworms can flourish only in soils that are well provided with organic matter.

Maintenance of Soil Organic Matter

One of the major problems confronting the farmer today is to maintain an adequate supply of organic matter in the soil. While there is a need to increase the organic matter level of some Illinois soils, it is not feasible to attempt to do so on others. In fact, experience has shown that it is difficult to increase the organic matter level of soil to any great extent. However, every reasonable attempt should be made to see that the organic matter in Illinois soils does not decline below present levels. The fact that organic matter is lost from the soil at a relatively slow rate, usually from 1 to 2 percent annually, while other properties affecting crop yields, such as structure, decline at a more rapid rate, indicates that there is a level of organic matter below which the soil will no longer be productive.

Since many of the desirable effects of organic matter are due to its dynamic properties, it is probably more important to concentrate on maintaining an adequate supply of actively decomposing organic residues in the soil than to try to increase the quantity of stable organic matter. Cropping practices that provide for the periodic return of abundant amounts of crop residues generally tend to maintain rather satisfactory organic matter levels. A good fertility program helps to maintain organic matter. Applying proper amounts of nitrogen, phosphate, and potash helps to increase yields, and the larger crops in turn produce large quantities of plant residues that can be returned to the soil after harvest.

Adding organic residues to the soil (1) improves soil structural relationships, (2) provides nutrients for plant growth, (3) improves permeability and retention of water, and (4) increases the numbers of beneficial soil organisms.

F. J. Stevenson
3-11-57

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AGRONOMY FACTS

SOIL FERTILITY AND TESTING

SF-48

THE AGRONOMIC SIGNIFICANCE OF WATER-SOLUBLE PHOSPHORUS IN FERTILIZERS

The phosphorus component in either normal or concentrated superphosphate has a high degree of water-solubility. Questions in regard to optimum water-solubility of phosphorus did not exist so long as fertilizers consisted of physical mixtures of superphosphate and nitrogen and potassium salts. Recent developments in fertilizer technology have, however, on the whole reduced the water-solubility of phosphorus in fertilizers. The problem is therefore receiving increasing attention.

The availability of phosphorus in fertilizers sold in the United States is officially reported in terms of citrate solubility. At present fertilizer laws do not require a separate statement indicating the amount of water-soluble phosphorus a fertilizer contains. The water-solubility of the phosphorus in the more common phosphate fertilizers is quite well known. Some of these fertilizers are listed in Table 1. On the other hand, the water-soluble phosphorus content of many commercial mixed fertilizers is not generally known except to the manufacturers. The water-solubility of phosphorus in "blended fertilizers," which are physical mixtures of nitrogen, potash, and superphosphate, is still considered to be satisfactory.

Table 1.--Solubility Characteristics of Some Common Processed Phosphate Materials

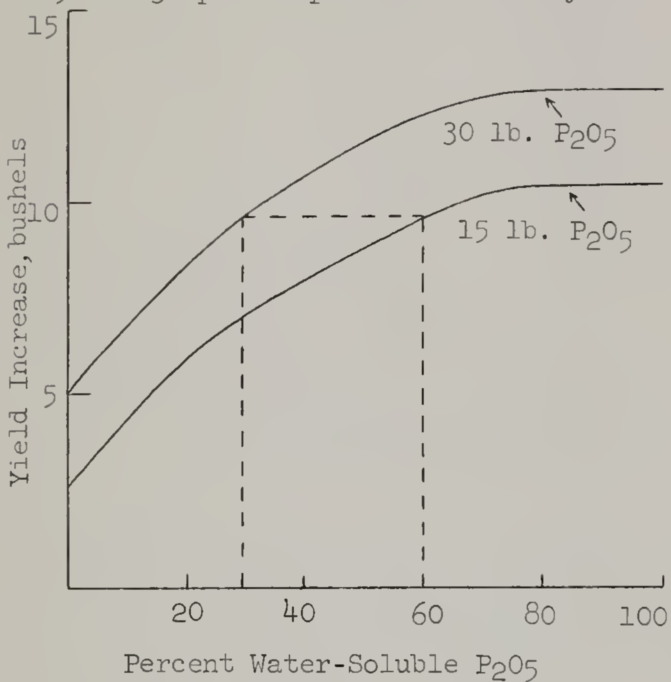
Material	Total % P_2O_5	Water-soluble	Citrate-soluble	Total available
Ammonium phosphate 11-48-0	49.3	89	9	98
Ammonium phosphate 16-20-0	21.1	86	12	98
20% superphosphate 0-20-0	20.5	78	18	96
Triple superphosphate 0-47-0	46.9	84	13	97
Dicalcium phosphate	40.4	5	91	96
Calcium metaphosphate	64.6	4	93	97

From "Soil and Fertilizer Phosphorus in Crop Nutrition," p. 306, Academic Press, Inc.

From these data it is obvious that one cannot judge the amount of water-soluble phosphorus in a fertilizer merely by looking at the <u>guaranteed total available</u> P_2O_5 on the tag. If the so-called <u>available</u> phosphates differ so much in water solubility, the important question is: "How much importance should we give to water-solubility when choosing phosphate fertilizers?" This question will be discussed here from the standpoints of (1) manner of application, (2) soil reaction or lime requirement, (3) leachability and carryover effects, and (4) available soil phosphorus test levels.

Band or Drilled Applications. Figure 1 shows the significance of water-soluble phosphorus banded in the row for corn on soils low in available phosphorus. It is evident that the water-solubility of the phosphorus in a fertilizer can become rather important when small amounts of phosphorus are band-applied to soils that are low in available phosphorus. For example, applying 15 pounds of P_2O_5 per acre with water-solubility of 60 percent will give the same yield increase as 30 pounds of P_2O_5 with a water-solubility of only 28 percent. On the other hand, a water-solubility in excess of 60 percent will give no further yield increases at either the 15- or 30-pound rate. In general, the water-solubility of phosphorus in banded fertilizers applied for corn or small grains to soils that are low in available phosphorus should not be less than 50 percent if maximum growth and yield increases are to be expected.

Figure 1. Effect of banding phosphates of varying water-solubility at rates of 15 and 30 pounds per acre on corn yields



Broadcast Applications. When phosphate is applied in accordance with soil tests, more phosphate is usually recommended, particularly on deficient soils, than can conveniently be applied with a planter fertilizer attachment. Under these conditions, most of the fertilizer must be broadcast and either disked in or plowed under. The significance of phosphate water-solubility in fertilizers applied broadcast to phosphate-deficient soil is shown by the data in Table 2.

Table 2.--Oat Yields With Broadcast Fertilizer Applications at Various Soil Reaction Levels

Carrier*	Water-soluble P_2O_5	pH** 5.7	6.9	7.9
None		54.8	66.4	62.9
Treble superphosphate 0-48-0	92	70.2	78.3	85.3
Calcium metaphosphate 0-62-0	4	69.8	77.0	77.3
Monoammonium phosphate 11-48-0	100	69.6	75.7	80.1
Diammonium phosphate 21-53-0	100	65.6	75.3	81.7

* Data courtesy of Dr. John Webb, Iowa State College, Ames, Iowa. Applied nitrogen and potash equalized for all treatments.

** pH 5.7 - 2.5 tons of lime needed; pH 6.9 - no lime needed; pH 7.9 - excessive free lime.

These data indicate, for moderately acid (pH 5.7 = 2.5 tons of lime needed) to neutral (pH 6.9 = no lime needed) soils, that similar oat yields can be obtained with phosphates varying from 4 to 100 percent in water-solubility. It is apparent on acid to neutral soils that the water-solubility of processed phosphate fertilizers is less important when fertilizer is broadcast than when it is applied in bands. However, for soils containing excessive free lime (pH 7.9), phosphates whose water-solubility varied from 92 to 100 percent produced significantly higher oat yields than did calcium metaphosphate of low water-solubility. On calcareous soils high water-solubility (comparable to that in superphosphate, Table 1) is to be desired in a phosphate fertilizer regardless of method of application.

Leachability and Carry-over Effects. To the uninformed, high-water solubility in a fertilizer implies leachability. The leachability of any plant nutrient, however, depends on the chemical reactions that the plant food in question undergoes when in contact with the soil. Under Illinois conditions, there is no danger that water-soluble phosphates will leach out of the soil.

The benefits of high water-solubility, particularly when phosphate is banded on phosphate-deficient soils, are strictly a single-year effect. In other words, the higher yields that one might expect from highly water-soluble phosphates the year of application (Figure 1) are not carried over into subsequent years. One reason for this limited effect is that the tillage carried out in preparing the seedbed scatters the previously banded fertilizer, bringing it into contact with more soil. Broadcasting is thus stimulated. And, as noted before, high water-solubility, particularly on acid to neutral soils, has less agronomic significance under this condition.

Soil Phosphorus Test Levels. In the previous discussions all of the yield data were secured on soils that were low in available phosphorus. The significance of phosphate water-solubility on soils testing slight, medium, or high in available phosphorus has not been reported in the literature. Since the yield response to available phosphorus decreases with increasing available soil phosphorus, it is logical to expect that the benefits previously noted (Figure 1) for phosphate water-solubility in excess of 50 percent on deficient soils would decrease as the soil phosphorus availability status improves. In other words, one might expect on soils testing S+ or better in phosphorus that a fertilizer of low water-solubility, such as calcium metaphosphate, would not be markedly inferior, even for starter purposes, to some other fertilizer with a much higher water-soluble phosphorus content.

E. H. Tyner
4-1-57

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

AGRONOMY FACTS

AND TESTING

SF-49

WHAT ABOUT FERTILIZING SOYBEANS

What about fertilizing soybeans? This question comes to the minds of almost all growers of the crop. To find the answer, researchers have been busy working at the problem throughout the soy belt. From the mass of information that has been collected, they have been able to establish certain definite principles of soybean fertilization:

1. Like other crops, soybeans require adequate plant food to produce highest yields.

2. They are not a poor-land crop even though they may do better on poor land than some other legume crops.

3. Unfertile soils cannot supply the nutrients needed for high production.

4. Only those soils that are high in fertility produce high yields.

To illustrate the soybean plant's need for nutrients we can compare 20 bushels of soybeans with 60 bushels of corn. Chemical analyses show that, on the average, 20 bushels of soybeans will contain more nitrogen, almost as much phosphorus, twice as much potassium, and four times as much calcium as 60 bushels of corn. Seemingly, since the soybean crop feeds so heavily on nutrients, it should respond well when fertilized. In general, however, the response to direct applications of fertilizer has been disappointing.

This can partially be explained by the fact that soybeans do not give the same response in bushels as most other farm crops. For example, in 1956 Illinois research studies corn yielded 29 bushels an acre on untreated land and 97 bushels on treated land. This is an increase of over 300 percent. Wheat under the same conditions yielded 14 bushels on untreated land and 49 bushels on treated land. This likewise is over 300 percent. Soybeans grown under the same conditions yielded 14 bushels an acre, the same as wheat, on the untreated land, but only 38 bushels an acre on treated land. This is considerably less than the 300 percent increase registered by the two other crops and 11 bushels an acre less than the increase in wheat yields. Soil management practices and fertilizer treatments were the same in all cases.

What Can Be Said About Fertilizing Soybeans

1. When grown on land that has been well managed and properly fertilized for other crops in the rotation, soybeans will produce well and are not likely to respond to additional applications of fertilizer or lime.

2. When they are to be grown on land that has not been adequately managed or limed or fertilized for other crops, then collect a good set of soil samples, at least 11 from each 40-acre field, and take them to a reliable soil testing laboratory and have them tested for limestone, phosphorus, and potash requirements.

Interpretations of the Soil Tests

1. Liming - If the soil needs two or more tons of lime per acre, soybeans will respond well to applications of limestone in accordance with needs as shown by the test. Best results will be secured if the limestone is broadcast and disked in after plowing and before the crop is planted. If time or money does not permit the needed heavy applications, then 200 to 400 pounds of fine lime drilled with the beans in the row at planting time will give good results. It must be remembered, however, that this is only a temporary measure

that is not likely to give as good a response as the full treatment and that it will not be beneficial for more than the one year.

2. Phosphorus - If soil tests show low phosphorus availability, soybeans may give some response to phosphate fertilization. The response will not be large, and it may not be consistent. Where small grains, particularly wheat, are following beans, then the two crops may be fertilized with phosphorus at one time by applying an adequate amount ahead of the beans.

   This is an especially good place to apply rock phosphate. There is always a possibility that the beans will respond to the phosphate fertilization and, even if they don't, the phosphorus will be in the soil, ready for the small grain and legume-grass seedings. If rock phosphate is used ahead of the beans, a small amount of superphosphate drilled with the small grain will be adequate for that crop.

3. Potash - Where potash tests are high, soybeans are not likely to respond to potash fertilizers. However, potash fertilization is highly recommended where soil tests show that the availability of potassium is medium or low.

   Potash fertilizing materials can be applied in several ways. The rate should be determined by the results of soil tests. Where the soil tests low in available potassium, 200 pounds of a potash fertilizer like 0-0-60 or its equivalent per acre in mixed fertilizers is recommended. If one plans ahead, the potash can be applied for the preceding crop, such as corn. Where this is done, the beans will need no further potash fertilizer and the response will be as good as if the material had been applied directly for the beans. However, if adequate quantities were not applied for the preceding crop, then additional potash fertilizer should be applied to make up the difference for the beans.

   Potash fertilizers should not come into contact with the seed at planting time. They should be either broadcast and disked in ahead of planting or applied at planting time with a fertilizer attachment on the planting equipment that will place the material at least two inches to the side of the seed and two inches below it. In soils that are not subject to compaction by rain, potash fertilizers may be plowed down preceding the bean crop. This practice, however, should not be used on those soils of the Cisne associations where plowed-down plant food may be sealed in by compaction of heavy rains.

A. L. Lang
4/8/57

AGRONOMY FACTS

SM-18

GRASSES FOR WATERWAYS

The effectiveness of grass sods in controlling erosion has long been recognized. The aboveground portions of the grass blanket the soil, the grass blades have a "shingling" effect, and the dense, fibrous root system holds the surface layers of soil in place. The value of grasses in resisting erosion from runoff water has been demonstrated at many soil conservation experiment stations.

The following data, which were taken on 8 to 9 percent slopes at the Dixon Springs Experiment Station show the difference in amounts of soil lost per acre for each inch of rainfall on land in grass compared with corn, wheat, and lespedeza:

Corn.................	1,444 pounds
Wheat.................	929 pounds
Lespedeza............	154 pounds
Pastures.............	6 pounds

The ideal waterway grass should possess the following qualities:

1. Ability to form a dense sod
2. Ability to establish itself quickly
3. Adaptation to a wide range of soil and moisture conditions
4. Resistance to trampling by livestock and travel of farm machinery

None of the grasses available to Illinois farmers fulfill all of these requirements. Several, however, give very satisfactory service under conditions to which they are adapted. To get best results, it is often advisable to use mixtures of grasses. Some of the grasses in the mixture may provide temporary protection while others are becoming established. Following is a description of the common grasses used in Illinois, with a summary of their qualities as waterway grasses.

Bluegrass. Where soil fertility is fairly high and moisture is adequate, bluegrass is very satisfactory for waterway use. It should not be seeded alone because it takes too long to establish a good sod. Where conditions are favorable, it should also not be included in seed mixtures, as it will establish itself and gradually take over the stand.

Because of its shallow root system, bluegrass may be damaged when exposed to runoff at high velocity. It is also subject to damage from trampling by livestock and travel of farm machinery, particularly in wet weather. Repairs to bluegrass waterways can, however, be made rather easily by patching with pieces of sod.

Timothy. This grass establishes itself rather quickly, but because of its shallow root system it does not form a dense enough sod when used alone. It also tends to be rather short lived. For these reasons it should be used in mixtures, where usually it will gradually be replaced in the stand by other grasses.

Redtop. Usually used in mixtures, redtop is especially good to use where drainage is poor and fertility is low. It is frequently seeded with timothy. This mixture establishes itself rather quickly, but where conditions are favorable it will gradually be replaced by bluegrass.

Tall fescue. Adapted to a wide range of conditions, tall fescue is one of our most useful waterway grasses. It establishes itself quickly, producing a dense growth with a very heavy root system. As a result it is not easily damaged by trampling of livestock and travel of farm machinery even in wet weather.

Because of the relative stiffness of the top growth, it "shingles" well and recovers well after heavy runoff in the waterway.

Smooth bromegrass. If one of the southern strains is used, bromegrass is one of the better waterway grasses to use in areas where soil and moisture are suitable. Where fertility is adequate, it establishes itself rather quickly, forms a heavy root system and a dense top growth, and gives good protection. Bluegrass will gradually take over the stand. Many bromegrass waterways were left in grass after the entire field had grown alfalfa-brome and the rest of the field had been plowed for corn.

Reed canary grass. This is the only grass adapted to Illinois conditions that will give good results in very wet, seepy waterways because it will grow and thrive when standing in water. It will, however, also do well under dry conditions, and it is adapted to a wide range of soils. Because it forms the heaviest root system of any of the grasses included here, it is suitable for channels where the velocity of runoff water is high. Unless kept clipped, it will spread through the lower parts of the watershed. It may be objectionable when slopes are fairly flat, as it may cause the channel to silt.

While the other grasses listed are usually established from seed, reed canary grass can be started in any one of three ways--from seed, from planting the stolens, or by tramping in the freshly cut green top growth in the early summer after the grass has jointed. The last method is effective only when the green cuttings can be tramped into the mud and water. Roots form quickly at the nodes when there is sufficient moisture.

Success with any of these grasses will depend to a great extent upon:

1. Preparing an adequate seedbed
2. Using pure seed of good quality
3. Keeping the fertility level high
4. Clipping the established stand frequently to keep the growth short and eliminate competition from weeds.
5. Protecting the waterway from physical damage and making repairs when needed.

W. F. Purnell
5-6-57

AVAILABLE WATER-HOLDING CAPACITY OF SOME ILLINOIS SOILS

To grow, plants need water in very large quantities. Approximately 20 acre-inches of water is used during a normal growing season to produce 100 bushels of corn per acre. Rainfall during the growing season supplies part of the water needed by crops. However, for successful crop production soils must store moisture and release it to growing crops as they need it.

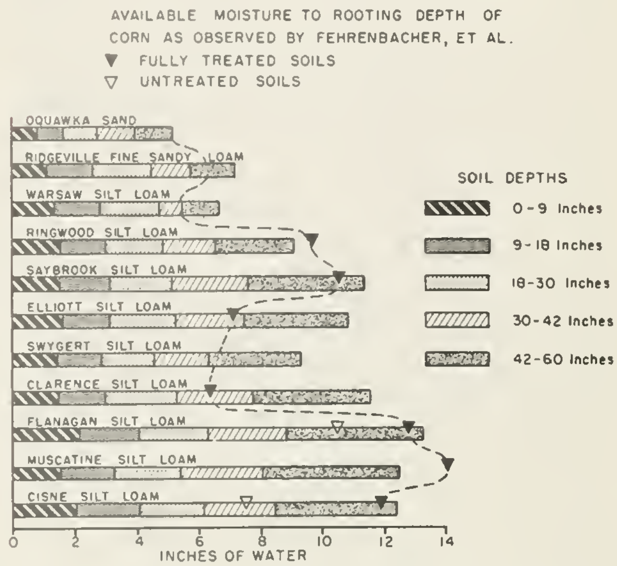
Soils differ widely in their total water-holding capacity. This capacity is closely related to soil texture. At field capacity fine-textured clays will hold about 0.5 inch of water per inch of soil, whereas loamy sands and sandy loams which contain less then 20% clay will hold only 0.1 to 0.2 inch of water per inch of soil.

However, fine-textured clays hold water so tenaciously that less than half of it is available to plants. In sandy soils, which contain little clay, a higher percent of the total water at field capacity is available to plants. Therefore, in soils of different texture, the amounts of plant-available water do not differ so much as the total amount of water at field capacity. In general, medium-textured soils (such as loams, silt loams, silty clay loams, etc.) have better moisture relations than either coarse-textured sandy soils or fine-textured clayey soils.

The purpose of this discussion is to indicate the available moisture-holding capacity of some important Illinois soils to a depth of 5 feet (Figure 1).

Oquawka sand* and Ridgeville fine sandy loam are representative of the sandy soils in Illinois. Oquawka sand, which holds only 5 inches of available water to a depth of 5 feet, is a drouthy soil (Figure 1). Ridgeville fine sandy loam can hold slightly more than 7 inches of available water to a depth of 5 feet and is less drouthy than Oquawka sand.

FIGURE 1
CUMULATIVE AMOUNT OF AVAILABLE MOISTURE HOLDING CAPACITY TO VARIOUS DEPTHS IN SELECTED ILLINOIS SOILS



The next six Brunizem soils in Figure 1 developed under grass vegetation from a thin covering of loess over different textures of calcareous glacial drift of Wisconsin age in northeastern Illinois. The six different textures of glacial drift are represented by the silt loam types of the Warsaw, Ringwood, Saybrook, Elliott, Swygert and Clarence series, which are listed in order of decreasing particle size of parent material from loamy gravel to clay. Warsaw, which is drouthy, has a low available water-holding capacity, especially in the

*Characteristics of this and other soils are described in Illinois Agricultural Experiment Station publication AG1443, "Illinois Soil Type Descriptions" (1950) and in Illinois Agricultural Experiment Station mimeographed publication AG1589a, "Characteristics of Some Important Illinois Soils" (1953).

coarse-textured material below a depth of 30 inches. Ringwood, which developed from sandy loam glacial till, is also somewhat limited in its available water-holding capacity. The other four dark-colored soils in this group, which developed from medium- to fine-textured glacial drift, can hold approximately 9.5 to 11.5 inches of water to a depth of 5 feet.

Soils that developed primarily from loess, such as Flanagan, Muscatine, and Cisne (Figure 1), appear to have larger available moisture-holding capacities than soils developed from glacial till. Flanagan silt loam is a dark-colored soil that developed from 3 to 5 feet of loess over calcareous loam glacial till in east-central Illinois. Muscatine silt loam is also dark-colored and developed from more than 5 feet of loess in western Illinois. Cisne silt loam is a strongly weathered claypan soil that developed in approximately 3 feet of loess over leached Illinoian till in south-central and southern Illinois. The favorable moisture characteristics of Flanagan and Muscatine are well known to persons who are familiar with these soils. However, it appears that the available moisture-holding capacity of Cisne silt loam is also satisfactory if plants can be induced to root deeply enough to use the moisture in the subsoil.

As is indicated in Figure 1, the available moisture-holding capacity of many Illinois soils is satisfactory, except those that have sandy horizons or that hold less than about 9 inches of available water in the upper 5 feet. However, plants do not use the available moisture in the upper 5 feet of all soils to the same extent because they root differently in various soils. Fehrenbacher, who studied the rooting of corn in 7 of the 11 soils in Figure 1, found that the corn rooted much deeper in some of them than in others. Comparisons show much greater differences in the available moisture to the rooting depth of corn than in the available moisture-holding capacity for these same soils to depths of 5 feet.

For example, Saybrook silt loam, which developed from permeable loam till, and Clarence silt loam, which developed from very slowly permeable clay till, can each hold approximately $11\frac{1}{2}$ inches of available moisture to a depth of 5 feet. According to studies by Fehrenbacher, corn roots to a depth of about $4\frac{1}{2}$ feet in Saybrook but only 3 feet in Clarence. The result is that the corn reaches approximately $10\frac{1}{2}$ inches of moisture in Saybrook but only $6\frac{1}{2}$ inches in Clarence. This explains why Clarence silt loam is drouthy even though it has a satisfactory available moisture-holding capacity.

In contrast, the favorable properties of Muscatine silt loam encourage corn to root deeper than 5 feet and reach more than 14 inches of available moisture if necessary. Hence, corn on Muscatine rarely suffers from lack of moisture even during long rainless periods.

Anything, such as soil treatment, that encourages deeper rooting increases the supply of available moisture that the plant can reach and use. This result is illustrated by the data for Cisne silt loam and Flanagan silt loam (Figure 1). Adequate fertilization on Cisne increased the depth to which corn roots penetrated from 3 feet on untreated areas to nearly 5 feet on fully treated areas. The moisture available to these rooting depths increased correspondingly from approximately $7\frac{1}{2}$ inches to 12 inches. On better soils, such as Flanagan, fertilization increases the rooting depth of corn and increases the amount of moisture available to the crops, but the increases are not so great as on Cisne.

R. T. Odell
12-10-56

POTENTIAL PRODUCTIVITY OF ILLINOIS SOILS

Most Illinois soils will produce more than they are now producing. Table 1 gives a broad picture of average crop yields that may be expected over a period of years under a moderately high and a high level of management in different parts of the state. Figure 1 shows five broad areas in which these yields may be obtained and which include the soils listed in the table. The yield figures given in the table were obtained from the results of long-time experimental fields of the University of Illinois1/, from Farm Bureau Farm Management Service records for the past 10 to 12 years2/, and from nitrogen studies by L. T. Kurtz for the years 1955 and 1956.

Table 1. Potential Productivity of Some Illinois Soils Under Various Management Levels

Area and soils3/	Crops	Average yield per acre by management levels: Mod. high	High
		bu.	bu.
Area I	Corn	73	81
Elliott, Ashkum	Oats	58	--
	Wheat	33	--
	Soybeans	30	--
	Hay*	2.5 tons	--
Area II	Corn	83	91
Tama, Muscatine	Oats	60	--
Sable, Ipava, Illiopolis,	Wheat	35	--
Flanagan, Drummer	Soybeans	33	--
	Hay*	2.5 tons	--
Area III	Corn	76	85
Herrick	Oats	57	--
	Wheat	32	--
	Soybeans	31	--
	Hay*	3.0 tons	--
Area IV	Corn	63	67
Cisne, Hoyleton	Oats	38	--
Cowden, Huey	Wheat	29	--
	Soybeans	29	--
	Hay*	2.0 tons	--
Area V	Corn	55	59
Ava, Wynoose, Bluford,	Winter oats	47	--
Grantsburg, Hosmer,	Wheat	27	--
Wartrace	Hay*	2.0 tons	--

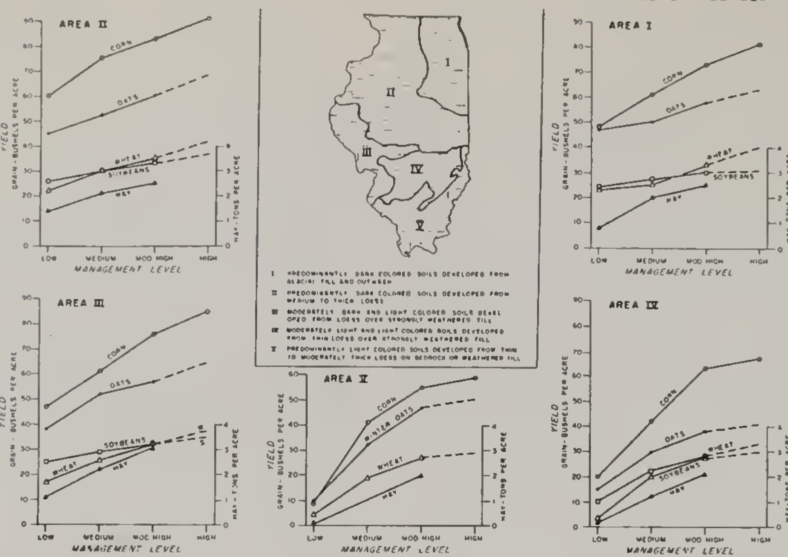
*Hay yield represents one cutting a year.

1/ Bauer, F. C. et al. Effects of soil treatment on soil productivity. Ill. Agr. Exp. Sta. Bul. 516 (1945). Recent data supplied by A. L. Lang and L. B. Miller.

2/ Rust, R. H. and R. T. Odell. Methods used in evaluating the productivity of some Illinois soils. Accepted for publication in SSSAP, Vol. 21 (1957).

3/ For detailed information on the distribution and characteristics of Illinois soil series in the various areas, see Ill. Agr. Exp. Sta. publication AG1443, "Illinois Soil Type Descriptions" (1950).

FIGURE 1 - PRODUCTIVITY OF SELECTED ILLINOIS SOILS UNDER DIFFERENT MANAGEMENT LEVELS



It should be emphasized that the yields shown in Table 1 give only a general picture of the productivity of representative soils in five broad regions of Illinois. Within each area some important soils are more productive than the figures in Table 1 indicate, and quite a few others are less productive. For example, in Area I the Saybrook, Lisbon, and Drummer soils are more productive than is indicated for Elliott, Ashkum in Table 1. In contrast, the Swygert, Bryce, and Clarence, Rowe soils are less productive than Elliott, Ashkum. Other very important soils not shown on the map are the bottomland soils, which occur in all areas of Illinois, and the sandy soils, which are locally important in Kankakee, Whiteside, Henderson, Mason, and Lawrence counties, and surrounding areas. In addition, the moderating influence of Lake Michigan tends to depress corn yields in Lake and Cook counties.

The weather will cause annual variations in crop yields from the figures in Table 1, which are averages covering a 10- to 12-year period. Annual variations of 20 percent from the average figures are fairly common. To maintain a long-time average yield of 90 bushels of corn an acre, it is necessary to achieve some annual yields of 110 bushels an acre or more in order to compensate for less favorable years when corn yields decline to 70 bushels an acre or lower.

The moderately high management level includes the application of phosphorus and potassium fertilizers and lime in amounts determined by soil tests, good crop rotations, application of manure or return of crop residues to the land, and improved drainage where necessary. The high level of management includes, in addition, providing for maximum yields by more intensive application of the recommended cultural practices and fertilizers mentioned above.

It should also be emphasized that the cost of applying recommended practices to the land should be balanced against the expected returns. For example, the soils in Area I are very responsive to phosphorus, moderately responsive to lime, and weakly responsive to potassium. The soils in Area II are moderately responsive to lime, weakly responsive to phosphorus, and very weakly responsive to potassium. The soils in Area III are quite responsive to lime, phosphorus, and potassium, and those in Areas IV and V, are very responsive to lime, phosphorus, and potassium. The responsiveness of the soils to the application of a certain type of practice or kind of fertilizer determines the return that can be obtained by applying the cultural practice or fertilizer in the management program.

L. J. McKenzie
3-21-57

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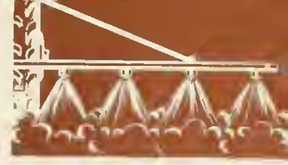
AGRONOMY FACTS



W-8

JOHNSONGRASS IN ILLINOIS

Johnsongrass was introduced into the United States about 1830 for use as a forage crop. Coming from Asia, it was first grown in North Carolina and soon spread throughout the Cotton Belt and the southern half of the United States. It has gradually moved northward until it can now be found anywhere in the southern half of Illinois. It is seen most often on bottomland soils but also grows profusely along railroads and highways and in other noncultivated areas.

Johnsongrass is a long-lived perennial grass that spreads both by underground roots and by seed. In appearance, it is difficult to distinguish from Sudangrass. Johnsongrass is not easy to control because it grows vigorously during July, August, and September. It spreads rapidly in corn and soybeans and cannot be controlled by cultivating.

Where Johnsongrass grows only in a few patches in fields, the most effective treatment is a chemical like Atlacide, sodium chlorate, or Dowpon. Treating these patches will prevent the weed from spreading further, even though the treatment will kill the crop planted near by. Atlacide is probably easiest to handle for very small clumps because a handful of it can be thrown on the clump. However, if the patches are much larger, Dowpon, which is equally effective, is much cheaper. Dowpon must be mixed with water and applied as a spray. Continual vigilance in eliminating small patches as they appear in cultivated fields is by far the easiest way to keep this pest from spreading.

If the infestation is solid, there are at present only two practical ways to eliminate it. One involves plowing ground planted to winter grain immediately after the grain is harvested and leaving it fallow the restof the summer. Winter grains can be grown several years in a row or they can be alternated with corn. After several years it may be possible to grow two crops of corn before returning it to small grains for one year.

Since wheat allotments restrict the amount of land on which wheat can be grown, the newer varieties of winter oats and winter barley should be used as a substitute for wheat.

After grain harvest the ground should be plowed and then disked or reworked at about three-week intervals for the rest of the season. This process will usually destroy most of the underground roots.

Where land is subject to overflow, the only known method of controlling Johnsongrass is to fallow the ground for one year. After fallowing, corn or soybeans can probably be grown for two years and then fallowing will have to be repeated.

This weed is less troublesome in central than in southern Illinois because the winters in the central section are more severe. Plowing infested areas in the fall will usually destroy a large part of the underground roots, but there are always enough roots below the plow sole to produce plants the next year. It is important to keep cultivated areas from becoming infested, and Dowpon should be

used in fencerows or other areas adjacent to cultivated ground to prevent the grass from spreading.

Every effort should be made to prevent Johnsongrass from producing seed. Recent studies in the Department of Agronomy show that seedlings with seven leaves have rhizomes as long as one inch. It takes only three to four weeks for a seedling to develop seven leaves. Our studies also indicate that a plant growing from seed in the spring will itself produce seed in seven to eight weeks and at the same time will produce an extensive underground root system.

This work indicates that if a permanent system of Johnsongrass control is to be developed it must include something to prevent seedlings from growing. Our present research program is aimed principally at this problem, because the old sod can be controlled by growing winter grains or fallowing, but we have found no good way to control seedlings.

Bob Schmerbauch
1-21-57

AGRONOMY FACTS

SOIL STERILANTS FOR WEED CONTROL

W-9

Soil sterilants are chemicals that are used to kill all vegetation. For this reason they are called nonselective. They work mainly through the soil. Enough chemical is applied to make the concentration in the soil high enough to kill root growth and any new seedlings that germinate. Usually no crop or vegetation will reappear for several months or possibly for as long as three to four years.

Soil sterilants are not new. Salt is one of the oldest. Certain industrial by-products have also been used in the past but because of transportation costs they have not been too important. Sodium chlorate, our most important soil sterilant, was introduced in 1925 and is still used on a large scale today. Atlacide contains sodium chlorate but it also contains calcium chloride, which reduces some of the hazard involved in the use of sodium chlorate.

The main uses for soil sterilants in Illinois are for spot-treating serious perennial weeds, treating fencerows to prevent vegetation, reducing vegetation around buildings and thus preventing danger from fires, and controlling vegetation along railroads and under public utility lines. Since soil sterilants are expensive, other means of weed control are usually tried first.

Soil sterilants are classified according to the length of time the residue remains in the soil. Temporary soil sterilants last from two to three months to as long as two years. Semipermanent soil sterilants usually last from two to four years. No sterilant is permanent because most materials eventually decompose or leach away in this section of the country.

The following temporary and semipermanent soil sterilants are now available:
Temporary: TCA, Dowpon, Atlacide, sodium chlorate, Erbon.
Semipermanent: Monuron, Fenuron, Diuron, boron compounds, sodium arsenite.

No one chemical can be recommended for all uses. Dowpon and TCA are preferable for controlling perennial grasses, and they leave a residue for not more than six months. Atlacide and sodium chlorate are preferable for treating perennial weeds in cropland areas because they kill most of the weeds and yet they usually disappear from the soil within one year or, at a maximum, two years.

Where long-time sterility is desired, as in fencerows or around buildings, then Monuron, Fenuron, Diuron, or boron compounds are best to use. Sodium arsenite is generally not recommended because it is extremely toxic to both man and animals. Erbon is a temporary sterilant that is somewhat similar to Atlacide and sodium chlorate, but very little experimental work has been done on it.

The chemical composition of these materials is given below:

TCA - trichloroacetic acid
Dowpon - 2,2-dichloropropionic acid
Atlacide - sodium chlorate and calcium chloride
Erbon - 2-(2,4,5-trichlorophenoxy) ethyl - 2,2-dichloropropionate
Monuron - 3-(p-chlorophenyl), 1,1-dimethylurea
Fenuron - 3-(phenyl)-1, 1-dimethylurea
Diuron - 3-(3,4-dichlorophenyl), 1,1-dimethylurea

There are many combinations of these chemicals on the market, particularly combinations of boron and chlorate and Monuron and chlorate. Rates for using them will be found on the container.

In using any soil sterilant, be sure to read the label carefully to determine the extent of its toxicity to both humans and animals.

F. W. Slife
3-4-57

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AGRONOMY FACTS

W-10

2,4-D-TYPE HERBICIDES FOR CONTROLLING BROADLEAVED WEEDS AND BRUSH

The 2,4-D-type herbicides (phenoxy compounds) were first used as selective weed killers in 1945. Since that time their use has expanded greatly, and today over 30 million pounds of these compounds are used annually for selective control of broadleaved weeds in crops and for other uses.

The most commonly used phenoxy compounds are 2,4-D (2-4-dichlorophenoxyacetic acid), 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), and MCP (2-methyl, 4-chlorophenoxyacetic acid). These compounds are used variously as post-emergence selective herbicides to control broadleaved weeds in corn, small grains, sorghums, and lawns, and brush and weeds in pastures, along roadsides, right-of-ways, and drainage ditches. Some 2,4-D may also be applied to the soil surface as a pre-emergence treatment to control broadleaved weeds and some grasses in corn and other crops.

Types of Phenoxyacetic Acid Compounds

The phenoxyacetic acid compounds are usually formulated and marketed as two basic types - salts and esters.

Amine Salts. The most widely used salts of 2,4-D, 2,4,5-T, and MCP and other phenoxy acids include such organic amine salts as diethanolamine, triethanolamine, alkanolamine, dimethylamine, triethylamine, isopropylamine, and others. These amine salts are formulated chiefly as water-soluble liquids. Other salt forms, such as sodium and ammonium salts, are seldom used.

The amine formulations of 2,4-D, 2,4,5-T, and MCP are relatively non-volatile and are safer to use in areas adjacent to susceptible crops and ornamentals than esters if spray drift is prevented. The amine 2,4-D should always be used to control weeds in lawns.

High- and Low-Volatile Esters. High-volatile esters of phenoxyacetic acid compounds include methyl, ethyl, isopropyl, butyl, and amyl. High-volatile esters of 2,4-D-type compounds are liquids, which form emulsions when mixed with water. The high-volatile esters should not be used under conditions of high temperature to control weeds in areas adjacent to susceptible crops, such as soybeans, cotton, tomatoes, grapes, flowers, and ornamentals. The esters should not be used within at least three miles of tomato fields; in these areas, other forms of 2,4-D should be considered.

The high-volatile esters of the phenoxy compounds are more phytotoxic per pound of acid equivalent than the amine forms. Thus for general usage only half as much ester acid per acre is recommended to control most weeds. The ester forms are absorbed by plants faster than the salts and thus are less likely to be affected by rainfall soon after application.

Low-volatile esters include butoxyethanol, propylene glycol butyl ether, butoxyethoxypropanol, ethoxyethoxypropanol, capryl, iso-octyl, and others with low vapor activity. The low- and high-volatile esters possess similar selectivity on annual weeds and crops in areas with moderate to low temperature and high humidity. Under high temperatures, which increase rates of evaporation and volatilization, the low-volatile esters have greater residual activity and persistence and are somewhat more effective on some species. Under most conditions, however, the low-volatile esters have greater activity for controlling annual weeds in crops and may be used at lower rates per acre.

The low-volatile esters are less hazardous than high-volatile esters in areas adjacent to susceptible crops, particularly when temperatures approach 100° F.

When field temperatures exceed 100° F., the vapors of both high- and low-volatile esters will cause injury, but the low volatiles will cause much less injury, to susceptible crops.

Use 2,4-D-Type Compounds With Care

Because misapplication of any 2,4-D-type compound can damage crops, certain precautions should be taken when spraying crop fields, fencerows, and lawns with 2,4-D, 2,4,5-T, or MCP. Spray drift, particularly of the ester formulations, can cause damage several hundred feet away from the area of application. The following suggestions will help to get the best results when using 2,4-D-type herbicides to control broadleaved weeds and brush:

1. Do not spray fencerows and around homes and gardens when the wind is blowing. Even if a non-volatile form of 2,4-D is used, small droplets or particles of the spray may be blown some distance and cause damage.

2. Read container labels and follow recommended rates very carefully. Accurately measure amounts of material to be used; do not guess. Rates in excess of recommended amounts can kill or severely injure some crops.

3. Calibrate sprayers to insure proper rate of application. This is very important where only very light rates of 2,4-D are required for weed control in low-tolerance crops like soybeans.

4. Use only the non-volatile or low-volatile forms of 2,4-D or 2,4,5-T brush killer around homes, gardens, or fields where sensitive plants are growing. Most horticultural crops and ornamental plants are sensitive to this chemical. For best results, spray when weeds are growing actively and the temperature is over 55° F.

5. To prevent excessive wind drift, maintain low spray pressures of 30 to 40 pounds per square inch (psi). Keep spray nozzles as close to the vegetation as possible. Use boom extensions or drop nozzles to apply 2,4-D spray in growing corn that is over eight inches tall.

6. Do not spray newly seeded lawns with 2,4-D. Wait three months after seeding. Do not spray bentgrass lawns. Do not mow lawns for several days before or after spraying.

7. Clean 2,4-D from spray equipment thoroughly to avoid contaminating other spray materials. If possible, use separate barrels or tanks for 2,4-D sprays. Do not use a wooden tank, as 2,4-D cannot be removed from wood. Following are two suggested methods for cleaning 2,4-D from spray equipment and metal tanks:

   a. Remove nozzles and drops from the boom and scrub thoroughly with kerosene. Add a box of non-sudsing detergent to 30 or 40 gallons of water, and run through pump and by-pass for five minutes and then out through boom. Partly fill tank with a solution of 1 to 2 percent household ammonia (1 to 2 quarts in 25 gallons of water, or 2 teaspoons per quart of water). Leave it in the sprayer (including hoses and boom) overnight and then rinse it out thoroughly with clear water.

   b. Rinse sprayer and tanks for at least two minutes with a 1 percent suspension of activated charcoal, followed by a complete water rinse.

It is nearly impossible to remove all traces of 2,4-D from equipment, but these suggested methods should minimize chances of damage to susceptible crops.

Rates of Phenoxy Compounds Are Based on Acid Equivalent

Because manufacturers formulate 2,4-D herbicides in solutions varying from 10 to 50 percent of active phenoxyacetic acid, it is impossible to make a general recommendation based on pints or quarts per acre. All rate recommendations are therefore based on acid equivalent. Most liquid formulations now on the market state the number of pounds of 2,4-D acid equivalent in one gallon of solution. Consider the cost per pound of actual acid when buying 2,4-D. Use this formula to calculate price per pound:

$$\frac{\text{cost per gallon of 2,4-D}}{\text{lb. of acid per gallon}} = \text{cost per pound of actual acid}$$

The following table lists the amount of liquid required per acre to give the suggested rate of acid per acre.

Table 1.--Amounts of Chemical Formulations of Various Strengths Required to Apply Various Rates of Acid per Acre

Pounds of acid desired per acre	Pounds of acid per gallon			
	2.0	2.9	3.3	4.0
	oz/A	oz/A	oz/A	oz/A
1/16	4	2.7	2.5	2
1/8	8	5.5	5	4
1/4	16	11	10	8
1/2	32	22	20	16
3/4	48	34	29	24
1	64	45	40	32

16 oz. = 1 pint, 32 oz. = 1 quart, 1 oz. = 2 tablespoons

Refer to Circular 771, "Chemical Control of Weeds and Brush," for specific recommendations on the use of 2,4-D, 2,4,5-T, and MCP.

Earl C. Spurrier
3-25-57

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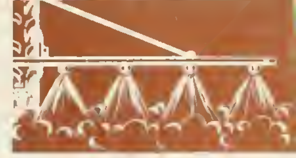

THE HERBICIDAL ACTION OF 2,4-D

2,4-D (2,4-dichlorophenoxyacetic acid) is one of several synthetic growth regulators related to the native growth hormone, indoleacetic acid (IAA). Compounds of this class when applied to plant tissue in very low concentrations cause the young cells to enlarge. In addition, they have many other regulatory effects, controlling the growth of buds and fruits, the abcission of leaves and fruits, the formation of roots and flowers, and the activity of the dividing cells in the stem (cambium). Indeed, these hormones exert such a profound influence on plants that scarcely any phase of growth or reproduction is unaffected by them.

The natural growth of plants is largely regulated by small amounts of IAA formed in the tips of stems and roots and translocated throughout the plant. There appears to be a sensitive enzymatic mechanism for maintaining a proper balance of the hormone, any excess being oxidized. However, there are limitations on the capacity of tissue to regulate hormone levels, and it was observed quite early that applications of high concentrations of IAA would inhibit growth rather than promote it. The synthetic growth regulators are particularly inhibitory if applied in excess, probably because the plant has little enzymatic capacity to destroy the compounds.

The synthetic hormones differ in some degree from IAA and from each other, and different compounds have different uses in agriculture, such as in rooting cuttings, promoting fruit set, and preventing premature fruit drop. Only 2,4-D and closely related phenoxyacetic acids have found wide use in growth inhibitory concentrations as herbicides. It was noted early in the last decade that 2,4-D was a remarkably potent growth regulator, and when tested as a herbicide it proved to be effective on many broadleafed (dicotyledonous) plants in amounts that did not appreciably injure grasses. Since many of the weeds that infest grain crops are broadleafed, 2,4-D has found ready acceptance as a commercial herbicide over the past decade. The inadequacy of 2,4-D for controlling grass weeds and some resistant broadleafed species is being met by the development of other kinds of herbicides, most of which are not in the auxin (growth promoting) classification.

A great deal of scientific effort has been directed at determining the mechanism of 2,4-D action as a selective herbicide. It is generally considered that growth hormones, like vitamins, act as co-factors in enzymatic reactions. Hormones, however, must regulate very sensitive and complex growth processes that have not yet been sufficiently isolated for biochemical study, and there is as yet no known enzymatic reaction in which any auxin acts as a co-factor. For the present, the action of 2,4-D must be described in terms of the physiological and morphological effects it has on plants.

An early statement about 2,4-D action was that "it makes plants grow themselves to death." This is not yet proved to be true. It is not even certain that the growth promoting effects shown by very small amounts of 2,4-D are related to its herbicidal effects. The grotesque growth shown by treated plants need not be related to the metabolic disturbances causing death.

What does happen when 2,4-D is sprayed on a susceptible plant? There are differences in the response of various species, but a few generalizations will hold for most dicots. First, the compound diffuses through the waxy cuticle covering the stems and leaves. This process is accelerated by the use of

esters and amines of the acid and by certain carriers with detergent properties. Some of the 2,4-D is actively accumulated by the underlying cells, and part is passed on through the tissue to the vascular bundles. Translocation occurs largely through the phloem cells, and appears to depend on the concurrent movement of sugars that have been photosynthesized in the leaves. If the plant is in a warm, well-lighted location, the 2,4-D will be translocated throughout the plant in a few hours.

One of the first effects of 2,4-D on the physiology of the plant is an increase in respiration, which is commonly accompanied by a decrease in photosynthesis. The net result is a diminution of the food reserves (sugars and starch). The respiratory change can be measured almost immediately before changes in growth rate are visible. The increase is believed to be due to an increased demand for energy by the enzymes that act with 2,4-D.

Growth changes are visible shortly after translocation is completed into any area. Stems and leaves are affected differently. The development of mesophyll tissue between the veins of young leaves is markedly inhibited, and a thick parenchymatous mass of tissue replaces the normal photosynthetic cells. The resulting leaves are small and thick with prominent, close-lying veins. The petioles and stems usually bend as a result of uneven growth. The meristematic areas at the base of the stem start to divide, with a consequent swelling of the stem. Under moist conditions young adventitious roots can arise in the swollen or callused areas. This proliferation of stem tissue tends to destroy the phloem cells, interrupting the sugar supply to the roots. In consequence, the roots in time are starved.

There is some discrepancy in studies on the effect 2,4-D has on root activity. Generally speaking, the salt- and water-absorbing capacity of the roots is diminished by 2,4-D, but under some circumstances there is an initial increase in absorption after the foliage is sprayed. This latter effect may result from a temporary increase in demand for nutrient elements in the stem, since the proliferating tissue is rich in these elements.

Many chemical analyses of 2,4-D-sprayed plants have been made, but no consistent picture emerges from them. Part of the reason is that a plant sprayed with 2,4-D dies by stages, several weeks sometimes elapsing before death. Plants that are rapidly succumbing will often be low in minerals, particularly potassium; the amount of inorganic phosphate compared with organic phosphate will be high; much of the nitrogen will be soluble, suggesting a breakdown of protein; and carbohydrate reserves will be low. But it is not clear whether these changes result from 2,4-D directly or from the fact that the plant is dying.

Studies have been made to determine the age at which plants are most susceptible to 2,4-D. In general, the seedling and flowering stages of growth are most sensitive, but there are some exceptions. Young, growing tissues are most susceptible to 2,4-D damage.

The relative insensitivity of grasses to 2,4-D is thought to be due to lower absorption and translocation, coupled with a lack of meristematic areas in the stem that proliferate and interrupt the phloem transport. In addition, it appears that the "growth" enzymes in grasses do not react so readily with 2,4-D. The insensitivity of some broadleafed weeds can also be best explained on this basis. Many perennial broadleafed weeds have powers of regenerating from rootstocks, making repeated applications of the herbicide essential.

In summary, present knowledge of 2,4-D action suggests that the herbicide effect has two bases: the compound shifts the delicately balanced metabolism of the cell into biochemical processes that will "rob" the normal developmental processes in young, expanding cells and stimulate uncontrolled cell division in the meristematic regions of the stem. Destruction of the photosynthesizing leaves and interruption of the transporting tissues causes the plant to starve for food, water, and mineral nutrients. Death follows. Resistant plants either do not absorb and translocate much of the chemical, or they have enzymatic systems that do not react readily with it.

J. B. Hanson
5-13-57